Marine Corps Systems Command
Combat Support Logistics Equipment and Training Systems Directorate
Quantico, VA 22134-5010

August 1999

Summary of Developmental Testing for the Light Strike Vehicle / Internally Transportable Vehicle Program

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13. ABSTRACT *(Maximum 200 words)*

This report compiles, in one source, the documentation of testing that has taken place in support of the Light Strike Vehicle (LSV)/ Internally Transportable Vehicle (ITV) Program. An extensive amount of testing has been undertaken and accomplished in anticipation of a Milestone I decision to proceed with development and fielding of the LSV/ITV. This report provides a consolidated reference of efforts conducted between 1993 and 1998. These efforts included early safety testing, developmental and comparison testing of an LSV surrogate with baseline Fast Attack Vehicles (FAVs) and the High Mobility Multipurpose Wheeled Vehicle (HMMWV), as well as continuing developmental and demonstration testing that was conducted by the Amphibious Warfare Technology (AWT) Directorate, Marine Corps Systems Command. Provided within this report are copies of past test reports and references to other test reports too voluminous to include.

14. SUBJECT TERMS

LSV	ITV	Fast Attack Vehicle
HMMWV	HTMMP	AEDT
JTEV	HTTV	Developmental Testing
V-22 Fitcheck	Urban Warrior	ATC/NATC

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APPENDICES

ABSTRACT

This report compiles, in one source, the documentation of testing that has taken place in support of the Light Strike Vehicle (LSV) / Internally Transportable Vehicle (ITV) Program. An extensive amount of testing has been undertaken and accomplished in anticipation of a Milestone I decision to proceed with development and fielding of the LSV / ITV. This report provides a consolidated reference of efforts conducted between 1993 and 1998. These efforts included early safety testing, developmental and comparison testing of an LSV surrogate with baseline Fast Attack Vehicles and HMMWV, as well as continuing developmental and demonstration testing that was conducted by the Amphibious Warfare Technology Directorate (Marine Corps Systems Command). Provided within this report are copies of past test reports and references to other test reports too voluminous to include.

1.0 INTRODUCTION

The requirement exists for a LSV that will provide a deployed Marine Air-Ground Task Force (MAGTF) and Marine Expeditionary Unit - Special Operations Capable (MEU-SOC) with a vehicle that is internally transportable in all medium and heavy lift rotary wing aircraft. The vehicle will serve the MAGTF and MEU primarily as a high mobility weapons platform to support a variety of operations, especially the amphibious raid. The secondary purpose of this vehicle is to provide reconnaissance units equal or greater mobility than the MAGTF maneuver elements they support, thereby enhancing their mission performance and survivability. The vehicle will provide Special Operation Forces with a ground mobility platform to support the five primary and other secondary missions that include special reconnaissance, direct action, unconventional warfare, foreign internal defense, counter-terrorism, personnel recovery and anti-terrorism.

The LSV and ITV is a lightweight, thin-skinned, highly mobile platform. It shall be internally transportable in the V-22 or larger aircraft, and has mobility equal to or greater than the Marine Air-Ground Task Force (MAGTF) maneuver elements. For quantification purposes, LSV shall achieve tactical high mobility greater than or equal to the High Mobility Multipurpose Wheeled Vehicle (HMMWV) as defined by tractive effort, obstacle performance, and maneuverability specifications. Ballistic protection offered by the LSV is minimal. Speed, maneuverability, and the use of cover and concealment are the crew's primary means of survival.

The LSV and ITV will assist with implementation of the United States Marine Corps' (USMC) concept of operation called Operational Maneuver from the Sea (OMFTS). The LSV program is designated as an ACAT IV-T program and is presently (FY99) in the Concept Exploration and Definition Phase, with Science and Technology efforts being conducted to determine the appropriate capabilities given the threat and requirements.

This report provides a summary of testing efforts that have taken place and been reported on throughout the course of the LSV / ITV program. The LSV / ITV was slated to begin development under an acquisition program beginning in 1993, but due to budgetary decisions, was put on hold. Developmental efforts conducted by the Amphibious Warfare Technology Directorate within the Marine Corps Systems Command continued to evolve the technology and gather test data to support the forthcoming acquisition decision.

2.0 SUMMARY OF TESTING

This report only addresses developmental testing conducted by the Marine Corps Systems Command and does not include Operational Testing or Evaluations that have taken place. During the course of these test initiatives, as much operational input has tried to be collected, and when done so within the test profile, it is included and reported.

Testing and reporting to date has been accomplished with four different test articles, as listed below and shown in Figures 1-4:

Helicopter Transportable Multi-Mission Platform (HTMMP) – Figure 1
Articulated Electric Drive Trailer (AEDT) – Figure 2
Joint Tactical Electric Vehicle (JTEV) – Figure 3
Helicopter Transportable Tactical Vehicle (HTTV) – Figure 4

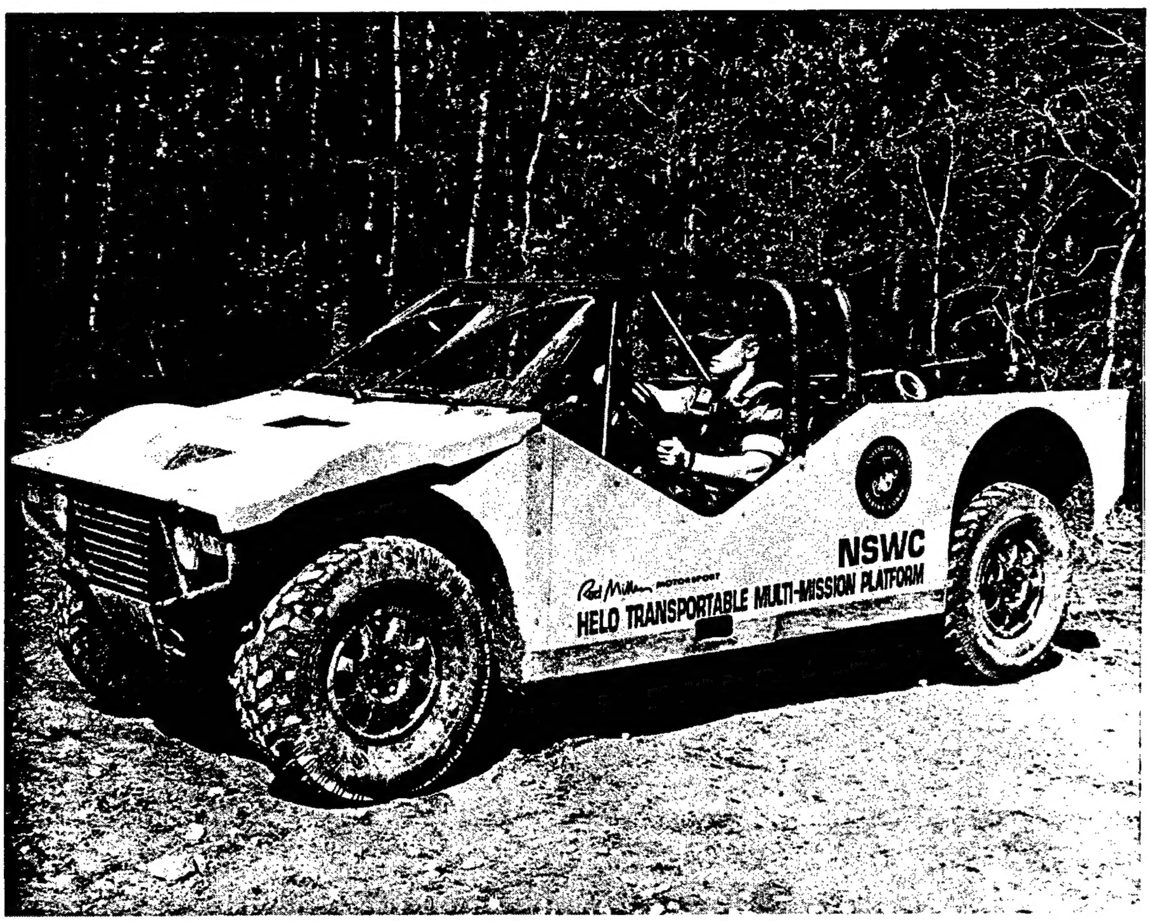

Figure 1 - Helicopter Transportable Multi-Mission Platform

Figure 2 - Articulated Electric Drive Trailer

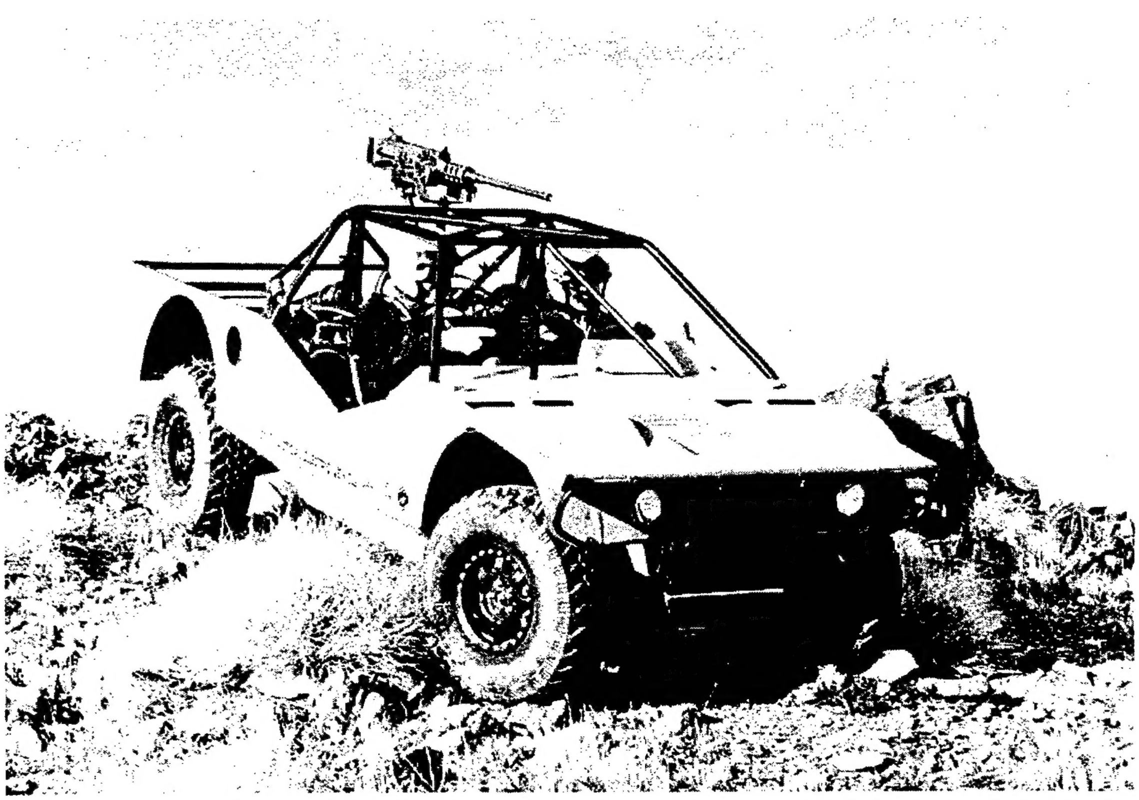

Figure 3- Joint Tactical Electric Vehicle

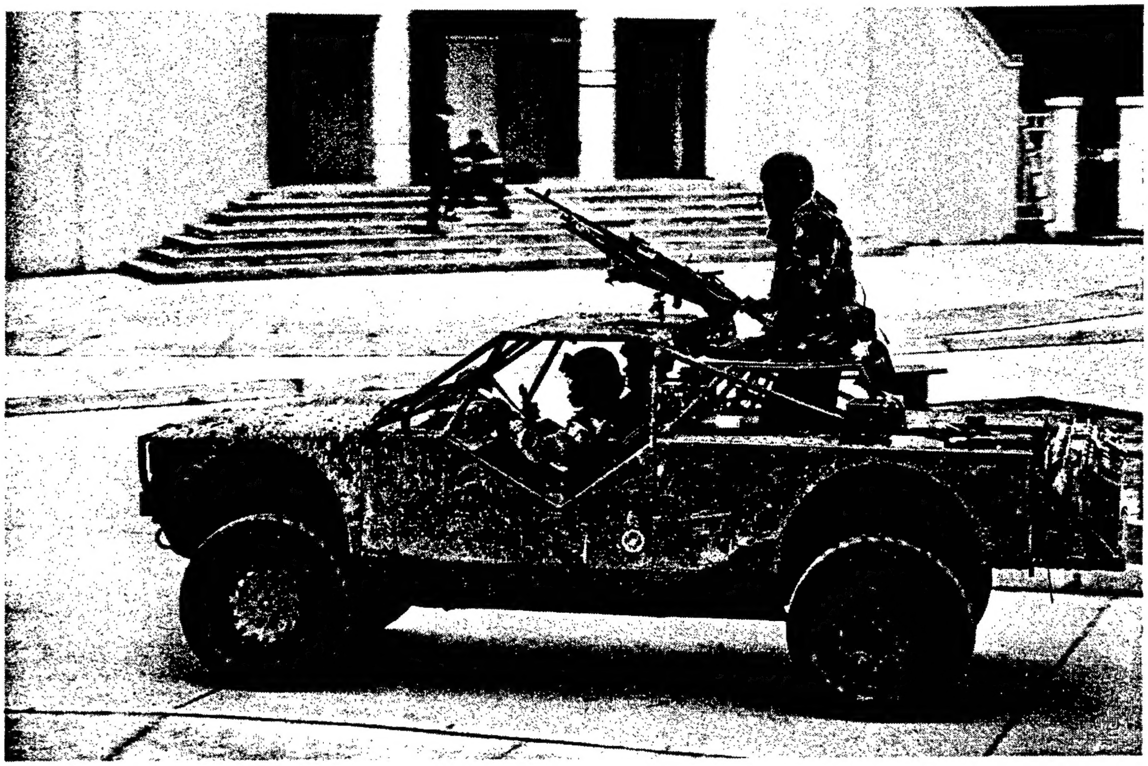

Figure 4 - Helicopter Transportable Tactical Vehicle

The following are summaries of test and evaluation initiatives conducted in support of the LSV/ITV. Full copies of most test reports are included, or if too large to be inserted, are referenced. Copies of all test reports are available for distribution on a need-to-know basis.

2.1 Test Series at the Nevada Automotive Test Center (1993)

In 1993, when the LSV program appeared headed for a Milestone Decision, a comparative test was conducted. Included in this test profile were the HTMMP, a High Mobility Multi-Purpose Wheeled Vehicle, a Chenowth Fast Attack Vehicle, and an M-151 Fast Attack Vehicle. Findings from this test supported the Cost and Operational Effectiveness Analysis (reference 2) that was conducted in the same year, and these platforms, as part of this test, were utilized in an Early Operational Assessment (reference 3).

Due to this reports size (4 linear feet of shelf space), the complete report is only listed under reference 1. Distribution is available from Naval Surface Warfare Center – Carderock Division or Marine Corps Systems Comment (Director – CSLE)

The Table of Contents from this report is provided as Appendix A.

2.2 Safety Release Testing at the Aberdeen Test Center (1997)

In support of User evaluations that were to take place with the HTTV (item 2.6 below), one of the three vehicles built was taken to Aberdeen Test Center and put through automotive technical tests, firing tests, and safety assessments prior to operator usage of the vehicle.

The complete report is provided as Appendix B.

2.3 Exploratory Development and Testing of the Articulated Electric Drive Trailer (1997)

Following successful demonstration of the HTTMP, the AEDT was developed to address a key user desire for increased payload capacity (trailer), while not adversely affecting mobility (powered wheels via electric drive). Articulation was incorporated to provide safety features and enhanced mobility through lock-out and selectable damping of motions between the host vehicle (HTMMP) and towed trailer. Testing was conducted and results are incorporated in this summary report.

Due to this reports size, the complete report is listed under reference 4. Distribution is available from Naval Surface Warfare Center – Carderock Division.

2.4 Exploratory Development and Testing of the Joint Tactical Electric Vehicle (1996)

Following successful demonstration of the HTTMP and the AEDT, the JTEV was developed to address an innovative drivetrain comprised of hybrid electric drive components. Utilizing commercial components from the electric vehicle industry and suspension components from the HTMMP, a new vehicle was developed and tested. Test results are incorporated in this summary report.

Due to this reports size, the complete report is listed under reference 5. Distribution is available from Naval Surface Warfare Center – Carderock Division.

2.5 Rollover Testing at the Aberdeen Test Center (1998)

With continued development of narrow vehicles to fulfill the Marine Corps unique requirement for internal V-22 and CH-53 transport, a series of tests at ATC were conducted to evaluate a spectrum of vehicle widths and payload center-of-gravities. The parameter of T/2H (T is vehicle track width, H is vertical center of gravity) was utilized as the independent variable, with 5 T/2H values being tested that correlate to currently developed or future vehicles. The relationship of T/2H as it relates to vehicle handling and safety was addressed. The characteristics of vehicle handling and safety that were addressed included: static tilt-table angle (see Figure 5), skid-pad lateral acceleration, and lane-change maneuver. The complete findings are provided in Appendix C, but summary findings are presented in Figures 6, 7 & 8, which show the trends and relationship of T/2H to vehicle characteristic.

The Test Report is provided as Appendix C.

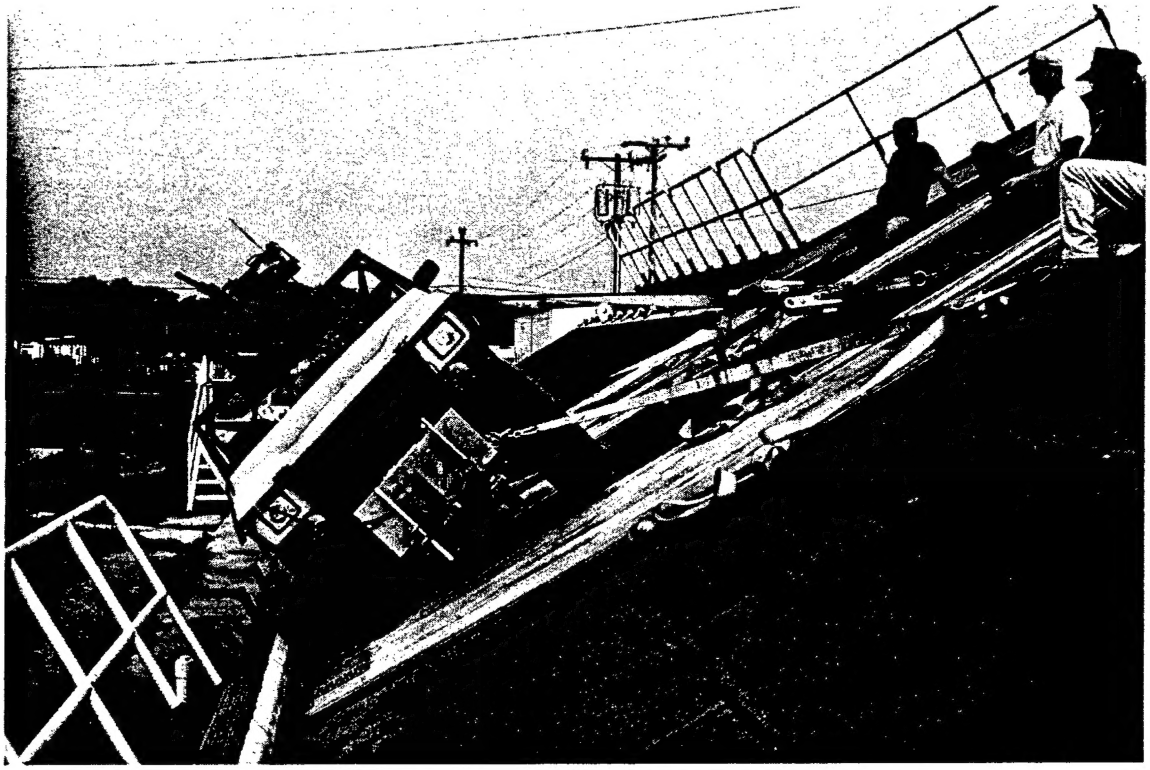

Figure 5 – HTTV on ATC Tilt Table

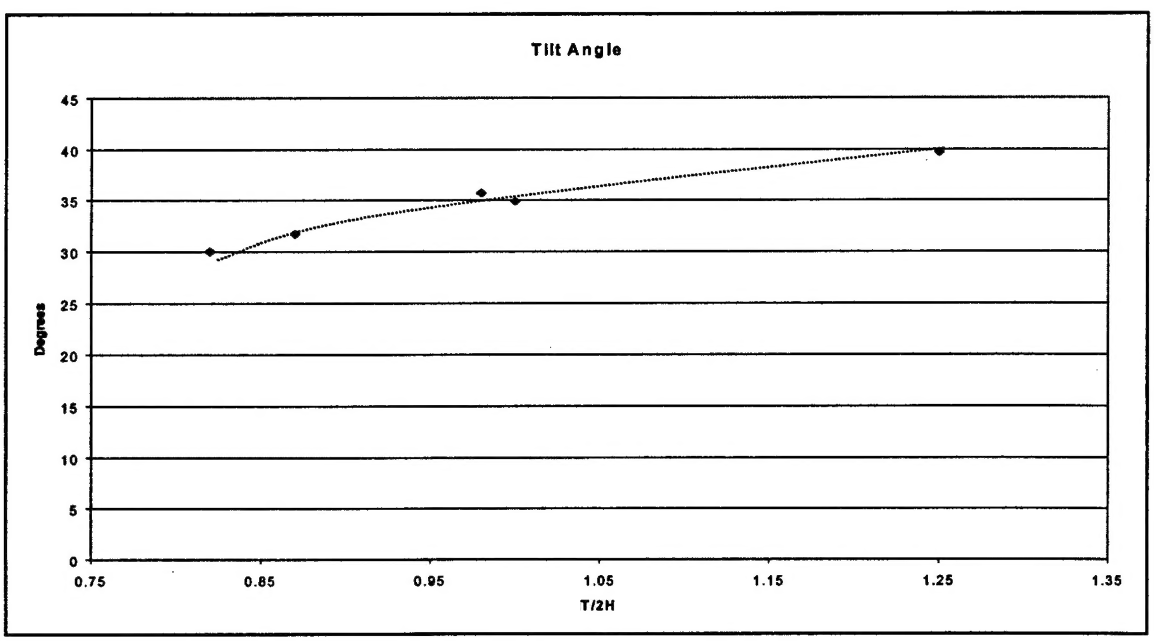

Figure 6 – Effect of T/2H on Tilt Table Angle

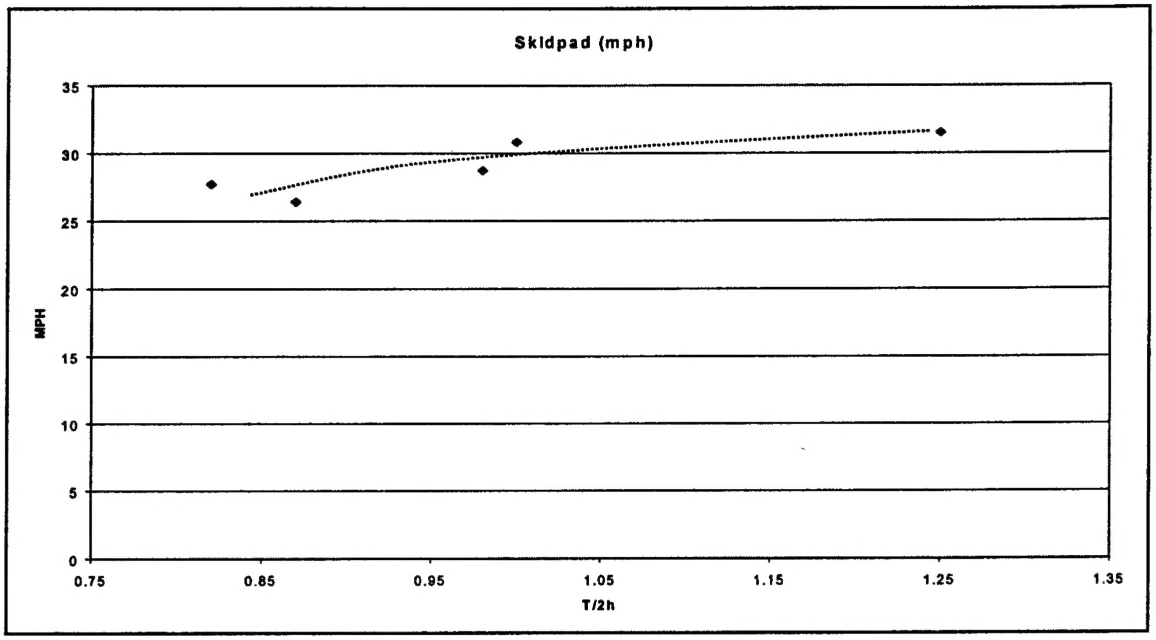

Figure 7 – Effect of T/2H on Lateral Acceleration

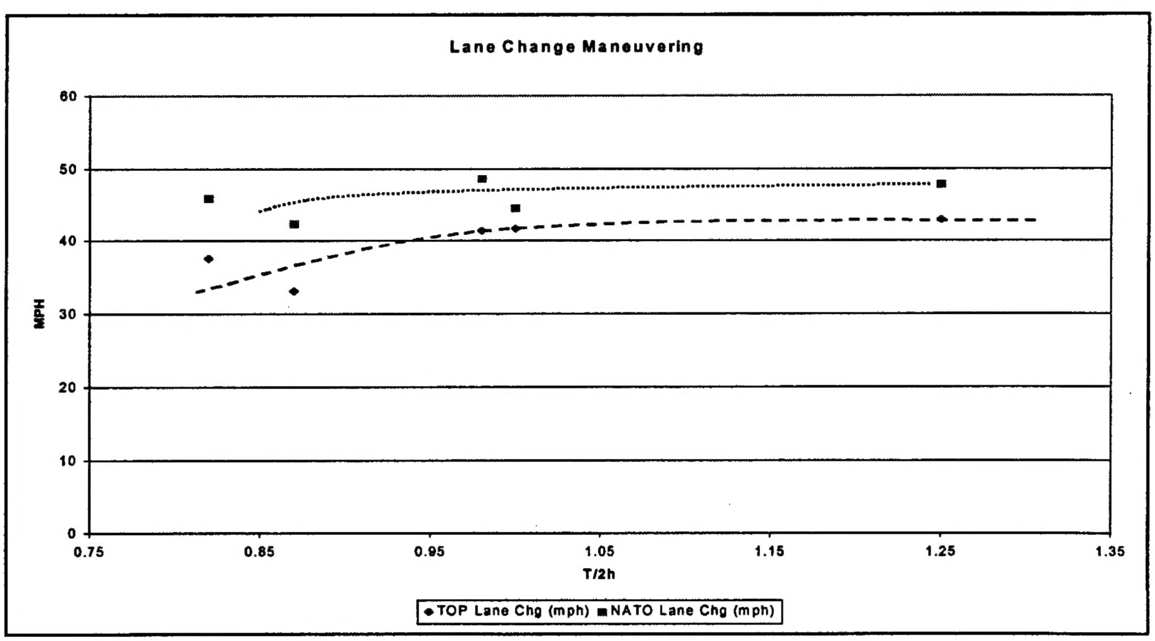

Figure 8 – Effect of T/2H on Lane Change Speed

2.6 User Evaluations with the Helo Transportable Tactical Vehicle (1998)

All three HTTVs and the AEDT were taken to US Special Operations Command Headquarters (MacDill Air Force Base, Florida) and the 5th Special Forces Group-ODA 596 (Fort Campbell, Kentucky). At both locations, the opportunity was given to users and developers to see and drive the HTTVs as a representative LSV. Narrative comments that were collected and user input for desires in future vehicles were captured and reported.

The Findings Report is provided as Appendix D.

2.7 V-22 Aircraft Fitcheck #1 (1996)

Utilizing the JTEV and a moth-balled V-22 aircraft, an interface test was conducted at Patuxent River Naval Air Station to assess fitting a ground vehicle into this new aircraft. In addition to a driving vehicle being tested, a non-functional mock-up was constructed and also incorporated in the test profile to explore the maximum vehicle envelope possible while still meeting aircraft dimensions. Measurements and photographic evidence is presented.

The Evaluation Report is provided as Appendix E.

2.8 V-22 Aircraft Fitcheck #2 (1998)

Utilizing one of the HTTVs and an MV-22 aircraft undergoing Operational Test and Evaluation, an interface test was conducted at New River Marine Corps Air Station to assess fitting a ground vehicle into this aircraft. Measurements and photographic evidence is presented in the two reports which address the issues from different perspectives. Shown in Figure 9 are representative views of the exercise.

Two Evaluation Reports are provided as Appendix F (Naval Air Warfare Center Lessons Learned Report – aircraft issues) and Appendix G (Naval Surface Warfare Center Lessons Learned Report – ground vehicle issues).

2.9 V-22 Aircraft Fitcheck #3 (1998)

Subsequent to the testing listed in items 2.7 and 2.8 above, on-going testing with an HTTV and the non-flying aircraft continue at Patuxent River. Unresolved issues with tie-downs and guide rail systems are addressed in the Quick Look Reports.

A Quick Look Report is provided as Appendix H.

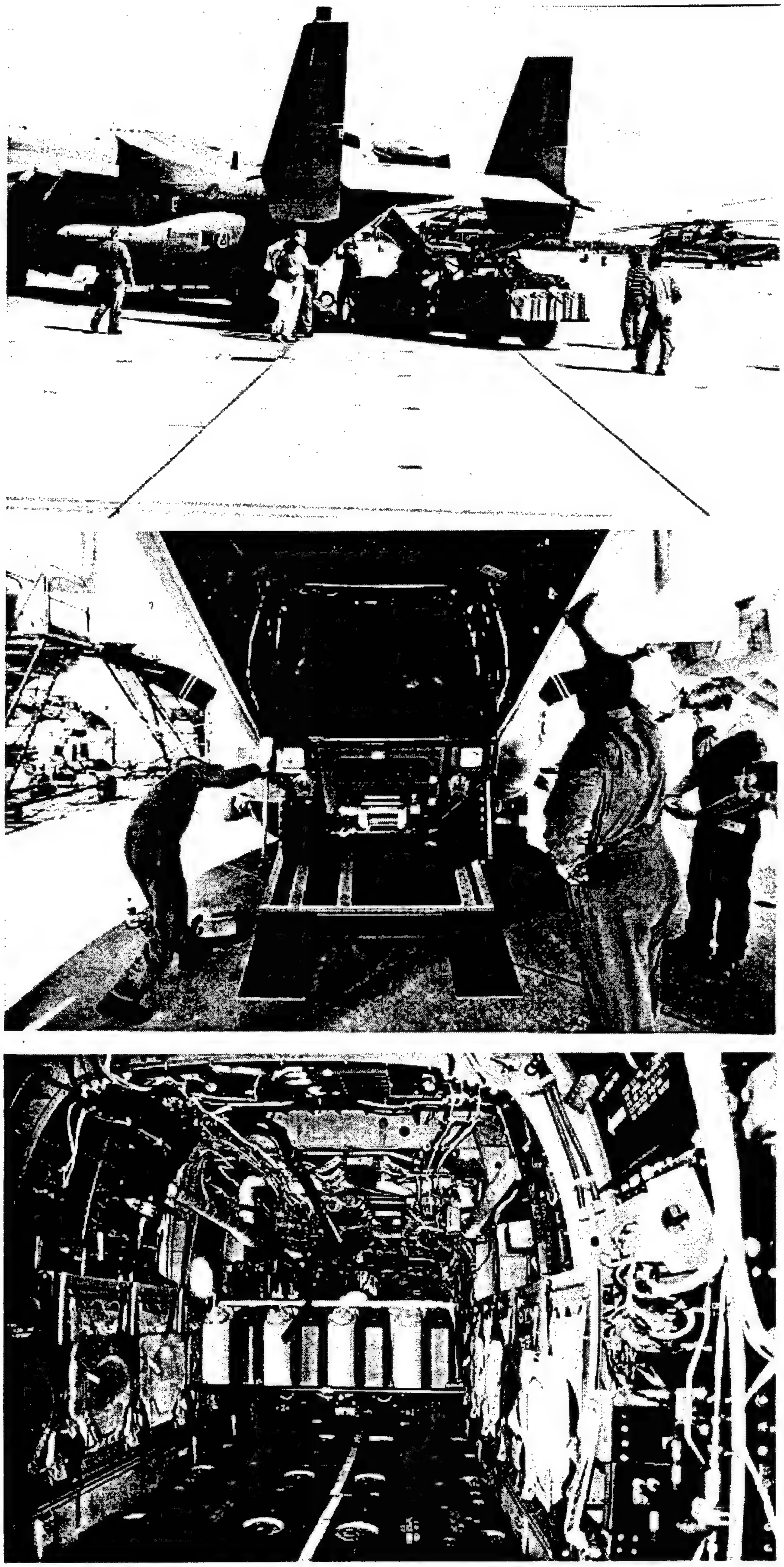

Figure 9 – Views of V-22 Fitcheck #2

2.10 URBAN WARRIOR Experiment (1998)

The HTTV was utilized by the Marine Corps Warfighting Laboratory to assess small unit delivery platforms and ways to sustain combat teams in an urban environment.

The portion of the URBAN WARRIOR Assessment Report dealing with mobility, HTTV usage and small vehicle assessment is provided as Appendix I.

2.11 User Evaluations and Payload Experiment (1999)

Two HTTVs were utilized by Army Special Operation Forces who are slated to receive LSVs once fielded. The platforms were utilized as surrogate LSVs to address notional payloads and how the vehicle would be utilized in the future.

This Assessment Report was originally written as a classified report, but will be provided as Appendix J once declassified.

2.12 Fuel Efficiency Testing with the Joint Tactical Electric Vehicle (1999)

As part of a more comprehensive initiative being sponsored by the Defense Advanced Research Projects Agency, a fuel efficiency test program is being conducted, utilizing several electric and hybrid electric vehicles. The JTEV is one of the vehicles in the test program.

The Test Report will be provided as Appendix K (once completed in October 1999).

2.13 URBAN WARRIOR Experiment (1999)

The FLYER, shown in Figure 10, was utilized by the Marine Corps Warfighting Laboratory during URBAN WARRIOR to assess light tactical vehicles in an urban environment.

A request was made to the MCWFL for copies of all findings relating to this vehicle during URBAN WARRIOR. Copies of all test results that were provided are reproduced in Appendix L.

Figure 10 – FLYER Vehicle

3.0 REFERENCES

1. "Test Program for the Light Strike Vehicle"; Nevada Automotive Test Center, Carson City, NV; October 1994

2. "Cost and Operational Effectiveness Analysis (COEA) for the LSV"; Marine Corps Combat Development Command - Studies and Analysis Division, Quantico, VA; May 1993

3. "Early Operational Assessment of the LSV"; Marine Corps Operational Test and Evaluation Activity, Quantico VA; December 1993

4 "A Test Program for Increasing the Off-Road Mobility of a Light Strike Reconnaissance Vehicle"; Rod Millen Special Vehicles, Huntington Beach, CA; March 1997

5. "Development of the Joint Tactical Electric Vehicle"; Naval Surface Warfare Center-Carderock Division, West Bethesda, MD; January 1996.

Appendix A

Test Series at the Nevada Automotive Test Center

NATC UNIVERSAL REPORT NO. 17-566
NATC PROJECT NO. 20-17-566
REPORT TITLE: LSV

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NATC UNIVERSAL REPORT NO. 17-566
NATC PROJECT NO. 20-17-566
REPORT TITLE: LSV

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NATC PROJECT NO. 20-17-566
REPORT TITLE: LSV

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VOLUME IDENTIFICATION

Appendix B

Safety Release Testing at the Aberdeen Test Center

DEPARTMENT OF THE ARMY
U. S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MARYLAND 21005-5059

REPLY TO
ATTENTION OF

STEAC-SF-A (70-10r)

MEMORANDUM FOR Commander, U.S. Army Test and Evaluation Command
ATTN: AMSTE-TM-S (R. Yowell)

SUBJECT: Safety Release Recommendations for the Helo Transportable Tactical Vehicle (HTTV), TECOM Project No. 1-CO-210-000-047

1. Subject document is forwarded for your approval.

2. Point of Contact at this center is Donald J. Lacey, Aberdeen Center for Sensing Technology, Soldier and Foreign Systems Business, DSN 298-0242, Commercial (410) 278-0242/0244.

FOR THE COMMANDER:

ORIGINAL SIGNED

Encl
as

JAMES W. FASIG
Technical Director

SAFETY RELEASE RECOMMENDATIONS

for the

HELO TRANSPORTABLE TACTICAL VEHICLE

(HTTV)

October 1997

Safety Release Recommendation

1.0 Purpose:

a. To identify any safety related problems and vehicle design deficiencies and identify those areas of concern which require correction prior to vehicle operation by user troops.

b. Provide instructions/operational recommendations to ensure the safety of personnel and to limit any damage to the Helo Transportable Tactical Vehicle systems. This safety release is applicable during the Limited User Demonstration (LUD) conducted at Ft. Campbell, KY.

2.0 References:

a. MEMORANDUM, TECOM, Test Directive, General Test Support, TECOM Project No. 1-CO-210-000-047.

b. AR 385-16, System Safety Engineering and Management, 3 May 1990.

c. MIL-STD-882C, System Safety Program Requirements, 4 May 1993.

d. MIL-STD-454K, Safety Design Criteria-Personnel Hazard, 14 Feb 86.

e. MIL-STD-1472D, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, 14 March 1989.

f. MIL-HDBK-759A (MI), Human Factors Engineering Design for Army Materiel, 30 Jun 81.

g. MIL-STD-1474B, Notice 2, Noise Limits for Army Materiel, 18 Jun 79.

h. DA PAM 40-501, Hearing Conservation, 27 August 1991.

i. NIOSH Pocket Guide to Chemical Hazards, U.S. Department of Health and Human Services, June 1994.

3.0 (U) System Description[a]

HELO TRANSPORTABLE TACTICAL VEHICLE

The Rod Millen built Helo Transportable Vehicle-HTTV-is designed to perform strike, reconnaissance and utility missions where extreme off-road mobility is required. Its high-speed (95+ mph) off-road mobility is unsurpassed in military vehicles. With adjustable ride height and fully locking differentials, it is unmatched in low-speed maneuver and obstacle clearance. The HTTV is V22 Osprey compatible, sized for internal aircraft transport yet capable of a 2000+

pound payload. This is the only light strike vehicle in existence that complements the V-22's range and speed.

The HTTV incorporates double A-arm independent suspension with long wheel travel to provide off-road mobility, high-speed maneuver and obstacle avoidance. It has a state-of-the-art passive off-road suspension with gas reservoir shock absorbers and coil springs yielding seventeen inches of wheel travel. As a comparison, the HMMWV has only eight inches of wheel travel available, bump to droop. The HTTV is equipped with hydraulic actuated ride height adjusters providing variable ground clearance between twelve and sixteen inches. It is powered at all four wheels with the General Motors 6.5 liter turbo diesel and 4L80-E automatic transmission. This is the same drive train that powers the up-armored HMMWV. The frame is constructed of high strength welded 4130 chromium molybdenum alloy steel tube and incorporates an integrated roll cage for crew safety and vehicle durability. The body is comprised of modular aluminum and fiber-glass panels which are easily removed for maintenance and replacement. The body panels can be replaced or supplemented enhance survivability as mission requirements dictate. The HTTV can be configured as a three crew member strike vehicle, a four passenger personnel transport or a two-seat cargo carrier.

The HTTV is a third generation vehicle built to be compatible with existing and future military medium lift rotary wing aircraft. The first vehicle, the Helo Transportable Multi-Mission Platform was sized for the CH-46 Sea Knight. As such, it was constrained not only by the physical dimensions of the aircraft's cargo bay but by the weight restrictions levied on the CH-46's aging airframe. The second light, wheeled military vehicle built by Rod Millen in conjunction with AeroVironment, Inc. was the Joint Tactical Electric Vehicle. This vehicle employs a hybrid electric drive train allowing for quiet operation and substantial energy storage for powering vehicle systems and sensors in a silent watch mode. This vehicle was built to be compatible with the V-22 Osprey medium lift replacement aircraft and fit checks in the V-22 have been performed to validate this capability. The HTTV draws from the lessons learned in building these military platforms combined with off road racing experience to provide a high performance, militarily useful light strike platform.

The HTTV design was based on the requirements of the USMC's Operational Requirements Document (ORD) for the Light Strike Vehicle (LSV). This document provides for a high mobility weapons platform and reconnaissance unit to replace the Fast Attack Vehicle currently employed throughout the Marine Air-Ground Task Force (MAGTS). The HTTV remedies the shortcomings and insufficiencies of the FAV, and unlike the HMMWV, it can be internally transported in current and projected Marine Corps rotary wing aircraft. The HTTV can be configured to support the following mission scenarios, amphibious raids, noncombatant evacuation operations, limited objective attacks, tactical recovery of aircraft and personnel, and ground reconnaissance.

4.0 Requirements

These Safety Release Recommendations are provided so a TECOM issued Safety Release can be developed to allow a Limited User Demonstration (LUD) with soldier operation of the HTTV. These safety release recommendations are applicable during the LUD, conducted at Ft. Campbell, NC. from 3 - 8 November 1997.

This safety release covers general areas of safety concerns. It is not intended to be an all inclusive safety evaluation addressing all tasks and functions performed by the crew operators or maintenance personnel. The HTTV vehicle is safe and reliable when used IAW the restrictions and recommendations documented in this Safety Release. Personnel should exercise caution and use safe operating practices when working on or around the vehicles. The vehicles are prototypes and have not under gone extensive testing. This Safety Release applies only to the two variants tested at ATC, the weapons carrier and the personnel carrier.

A Safety Assessment Report, Hazards Tracking Document or Occupational Health Hazards Report was not provided with the vehicle. The testing required to provide this Safety Release was based on input from experienced operators, engineers, and mechanics at ATC.

Safety and automotive tests were conducted with the vehicle at a total Gross Vehicle Weight of 6,480 lb. A load diagram was not provided with either vehicle. The vehicle weight with personnel, combat load, weapons and ammunition can not exceed the weight of 6,480 lb. A description of the loading equipment and stowage plan used for testing the Weapons Carrier are contained in Table 1, Enclosure 1.

The HTTV's are small lightweight vehicles, with the same turbo charged 6.5 liter engine and transmission as the uparmored High Mobility Multi-purpose Wheeled Vehicle (HMMWV) but at half the weight. The vehicles have a lot of power and a very tight turning radius. Personnel should exercise good judgment and use safe operating practices when driving the vehicles. Only experienced qualified licensed operators may drive the vehicles.

a. The following restrictions/requirements apply to both HTTV vehicle variants:

1. Operators **<u>must</u>** complete a vehicle-specific training course conducted by the responsible vehicle contractors/government personnel. The training course should be designed toward providing new equipment training of the modified equipment and **identify any hazards associated with driving the vehicles.**

2. Kevlar helmets, will be worn by vehicle operators/crew, to provide protection to the head area, when operating the vehicle. Noise levels measured in the HTTV vehicle do not exceed the requirements for single hearing protection. However during any weapons firing single hearing protection, protective goggles, and clothing (BDU's) must be worn.

3. Personnel from Maritime Applied Physics Corporation will be required to conduct daily Preventive Maintenance Checks and Services (PMCS) on the vehicles and correct any areas of discrepancy. There are no operators manuals for either system, and access to the internal fluid reservoirs requires removal of hardware in most cases. Contractor personnel will be required to perform all maintenance and repairs on the vehicle as required.

4. Due to the limited adjustment of the 5-point seat harness and the low design of the drivers seat only personnel that meet the anthropometric measurements of greater than 40% male (Table 2, Enclosure 1, for Anthropometric Dimensions) are allowed to occupy the front seats of either vehicle during operations. The 5-point seat harnesses should be secured tightly around personnel to prevent choking when stopping. The 5-pointseat harnesses are installed on the front seats of both variants.

Due to the minimal line of sight to the nearest ground surface when seated in the driver's seat, only personnel that meet the anthropometric measurements of a 60% male or greater are allowed to drive the HTTV.

5. Weapons Carrier:

The weapons systems have not been fully evaluated on the HTTV system, the weapons ring and mounting arm were designed to work in conjunction with the new MK 93 Dual weapons mount. This is the mount the HTTV was tested with and this must be the mount used for any weapons firing. The HTTV was tested with the MK 19 weapon and .50 caliber machine gun. These are the only two weapons that may be used for any weapons firing. The following restrictions apply when firing the weapon:

(a) The operation of the weapons (MK 19 or .50 cal) is limited to personnel that meet the height requirements of a 40% male or greater. This ensures operators (gunners) have adequate line-of-sight over the weapon.

(b) The weapon system may only be fired from a stationary position. Moving vehicle firings are prohibited.

(c) Due to the inoperability of the weapons depression stop, the T & E bar **must** be attached to MK 93 weapon mount so that the weapon cannot be depressed. Occupied (driver and passenger) vehicle firings over the front of the vehicle are prohibited.

6. Personnel Carrier:

(a) The rear passengers are not protected by the roll bar assembly in the event of a vehicle roll over. A roll bar assembly **must** be integrated into the existing roll bar to provide rollover protection for the personnel sitting in the rear of the vehicle. If a roll bar is not added personnel are prohibited from riding in the two rear seats.

7. The following restrictions apply to both HTTV vehicles when driving the vehicles during the LUD:

(a) The primary operating mode for vehicle suspension should be in the lowered position for both on and off road operations. The suspension should only be operated in the raised position when required to maneuver obstacles. Prolonged operating and maneuvers over off road terrain could cause a premature failure of the power steering pump which also powers the hydraulics for the suspension.

(b) When operating on paved or graveled roads operators will observe the local speed limit for that road or for the installation.

(c) Off road operations should be limited to 48 kph (30 mph) with the suspension lowered and 16 kph (10 mph) with the suspension raised. This low speed should minimize the sloshing of hydraulic fluid in the reservoir which can cause power steering pump to cavitate due to air being drawn into the supply line to the pump.

b. The following safety concerns **must** be corrected prior to the start of the LUD:

1. The drivers emergency brake was inoperative on the two vehicles tested. The emergency brake must be repaired so it is functional and a label attached identifying it as the emergency brake. A label should also be installed to indicate that to set the emergency parking brake the operator needs to "PULL" the handle to set the brake. The operation of the brake should be covered during the training.

2. A nylon webbing support must be attached to the drivers and passengers entrance area to secure personnel extremities to the inside of the vehicle in the event of a rollover.

3. The vehicle will start in any gear, provide a lockout so that the vehicle will only start when the gear shift is in "PARK" or : "NEUTRAL".

4. Blackout drive lights and markers must be added for night operation, with Night Vision Goggles (NVG).

5. Rear view mirrors must be added to the HTTV personnel carrier to provide rearward visibility. When the driver and passenger are secured in the 5-point harness, the harnesses do not allow an adequate amount of movement of the torso for turning laterally or looking behind.

6. A fire extinguisher (type BC, 5-lb, portable) must be installed in each vehicle, and placed where it is accessible to all crew members.

c. The following are potential hazards with the HTTV that the operators need to be aware of during operations:

1. Weapons Carrier

a. There is no backrest or harness attached to the weapons ring. Personnel can be thrown from the turret ring when traversing cross-country in a firing position. The firing platform the gunner stands on is the seat pad of the gunners seat.

b. Top of weapons ring mount is below 5th percentile female waist measurement when standing on the seat pan. Maintaining stability when trying to fire the weapon is very difficult. The height from the seat pan to the top of the weapons ring mount should be able to accommodate a 95 % male torso measurements.

c. The depression stop does not work, the gunner can shoot the front of the vehicle if the weapon gets away from them during firing.

d. There is considerable flex in the weapons ring mount arm when firing the weapon over any of the four sides. A visual inspection of the weapons ring mount arm and mount should be performed before and after any firing exercises.

e. While firing the weapons over the drivers or passengers side, the weapon mounting ring wants to walk to the left. There are no mounting ring locking pin positions for firing over the drivers or passengers side.

2. Personnel Carrier

a. The forward rear passenger seat should be fitted with a 5-point harness to prevent that persons head from striking the roll bar during a panic stop.

b. The foot space for the rear passenger is extremely limited.

d. The following problems were noted on the HTTV's which should be addressed to make the vehicle safer to operate during the LUD and in the event of future development:

1. Provide a support to hold the engine cover up for accessibility to check fluids.
2. Provide internal communications for each personnel station.
3. Provide access to enable personnel to check engine compartment fluids.
4. A red fuel cap covers the inlet for the fuel tank, for diesel fuel a yellow cap should be installed or a cap the same color as the vehicle with a label indicating "diesel fuel only".
5. The tire lug nut only engage ½ of the wheel studs when tight.
6. There is no apparent way to "Slave Start" the vehicle.
7. No trailer light hookups for either vehicle.
8. Tow pintle cannot be used with tail gate open.

9. The negative and positive battery leads are not covered.
10. The toggle switches that control suspension height are not labeled. Provide labels to indicate function of switches.
11. The water cans when stowed on the rear tail gate of the weapons carrier block the rear light assemblies.
12. The brake pedal is very close to the accelerator pedal, drivers could inadvertently hit the accelerator pedal instead of the brake.

5.0 Background and Testing

a. The Safety Assessment Report for the system was not received.

b. A copy of the Safety and HFE test results can be obtained by contacting Donald J. Lacey, at Aberdeen Test Center (ATC), Aberdeen Center for Sensing Technology, ATTN: STEACS-SF-A, Aberdeen Proving Ground, MD 21005-5059. Telephonically at DSN 298-0242 or (410) 278-0242.

6.0 Conclusions and Recommendations

The vehicle is considered safe for military personnel to ride in and operate, provided the conditions stated in paragraph 4.0.a, 4.0.b and 4.0.c are followed. Vehicle firings are only permitted if the vehicle is stationary and the T & E bar from the weapons ring mount is attached so that the weapon can only be fired at that elevation angle. Weapons firing while the vehicle is moving are prohibited. To make the vehicle safer during operations it is suggested that the items in paragraph 4.0.d be addressed.

TABLE 1. STOWAGE EQUIPMENT AND LOAD PLAN

The following items and associated weights were stowed on the HTTV Weapons Carrier to simulate an actual vehicle weight when tested. A stowage plan was not provided with the vehicle. The vehicle fuel tank was filled before getting a final weight.

NOMENCLATURE:	QTY	WEIGHT EA kg (lbs)	TOTAL kgs (lbs)
MK 19 Weapon and MK 93 Mount	1	165 (75)	165 (75)
MK 19 Ammo Can	5	132 (60)	660 (300)
.50 Caliber Ammo Can	8	66 (30)	528 (240)
5-Gallon Water Can	8	88 (40)	704 (320)
Camouflage Netting	1	66 (30)	66 (30)
"Water Babies"	2	440.4(200)	880.8 (400)

The MK 19 and MK 93 were mounted on the mounting ring weapons support arm. One MK 19 ammo can was attached to the MK 19 weapon. Four MK 19 ammo cans were stowed in the rear of the vehicle between the wheel wells along with two .50 cal ammo cans. Eight .50 cal ammo cans were placed in the ammo storage rack on top of the left wheel sponson. Eight water cans were placed on the rear tailgate. The camouflage netting bag was secured on top of the right sponson. The "water Babies" were placed in the two passengers seats and an ATC driver occupied the drivers seat.

TABLE 2. ANTHROPOMETRIC MEASUREMENTS

Percentile	Male Eye Height Sitting	Male Eye Height Standing	Male Stature Sitting	Male Stature Standing	Female Eye Height Sitting	Female Eye Height Standing	Female Stature Sitting	Female Stature Standing
5	28.94	60.20	33.64	64.84	26.95	55.70	31.31	60.15
10	29.43	60.67	34.17	65.76	27.40	56.15	31.77	61.01
15	29.77	61.13	34.52	66.39	27.71	56.60	32.09	61.59
20	30.04	61.60	34.80	66.88	27.96	57.15	32.35	72.04
25	30.27	62.06	35.13	67.32	28.17	57.50	32.58	62.43
30	30.47	62.53	35.25	67.71	28.37	57.95	32.79	62.79
35	30.66	63.00	35.44	68.07	28.55	58.40	32.98	63.12
40	30.84	63.47	35.63	68.42	28.72	58.85	33.16	63.44
45	31.02	63.93	35.81	68.76	28.89	59.30	33.34	63.75
50	31.19	64.40	35.99	69.09	29.06	59.75	33.52	64.06
55	31.36	64.87	36.17	69.43	29.23	60.20	33.70	64.38
60	31.54	65.33	36.35	69.77	29.40	60.65	33.88	64.70
65	31.72	65.80	36.54	70.12	29.58	61.10	34.06	65.04
70	31.90	66.27	36.74	70.50	29.77	61.55	34.26	65.40
75	32.11	66.73	36.95	70.90	29.97	62.00	34.48	65.80
80	32.33	67.20	37.19	71.35	30.20	62.45	34.71	66.25
85	32.59	67.67	37.46	71.88	30.46	62.90	34.99	66.77
90	32.92	68.13	37.79	72.53	30.79	63.35	35.33	67.43
95	33.39	68.60	38.26	73.48	31.27	63.80	35.84	68.40

TABLE 3. HTTV SPECIFICATIONS

DEMINSIONS		
Length	4.42 meters	174 in
Width	1.57 meters	62 in
Height (variable)	1.65 meters	65 in
Wheel Base	3.05 meters	120 in
Track Width	1.31 meters	51.5 in
Approach Angle (w/o winch)	60 degrees	
Departure Angle	60 degrees	
Ground Clearance (variable)	0.30-0.41 meters	10-16 in
Tire Size	35x12.SCR17 LT	
WEIGHT/MASS		
Curb Weight	1901 kg	4200 lbs
Payload Weight	909 kg	2000+ lbs
GVW	2818 kg	6200+ lbs
DRIVETRAIN		
Engine Type	GM Turbo Diesel	
Configuration/# of cylinders	V8	
Displacement	6.5 liter	395 cu in
Maximum Horsepower	190 hp @3400 rpm	
Maximum Torque	385 lb ft @1800 rpm	
Transmission Type	4-speed Automatic, 41.80-E Hydramatic	
		Maximum Transmission
Torque Rating	597 N-m	440 lb ft
Maximum Gear Box Torque	1200 N-m	885 lb ft
Ratios (1st-4th, Reverse)	6.751/4.031/2.720/2.040/5.649	
PERFORMANCE		
Maximum Speed	150+ kph	95+ mph
Acceleration (0-50 kph/30 mph)	less than 4 seconds	
Acceleration (0-100 kph/60 mph)	less than 13 seconds	
Range	550 km 3	40 miles
Maximum Grade	60%	
Side Slope Stability	40%	
Ford Depth (w/o kit)	1.2 meters	30 inches
Vehicle Core Index (VCI)	16.4	

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005-5055

REPLY TO
ATTENTION OF

AMSTE-TM-S (70-10p)

4 NOV 1997

MEMORANDUM FOR:

Commander, CARDEROCK Division, Naval Surface Warfare Center, 9500 MacArther Rd. ATTN: Mike Byerly, West Bethesda, MD 20817-5700

Commander, ODA-596 3/5th SFG, ATTN: Adam Such, Bldg 6801, Stillwell Rd. Fort Cambell, KY 42223

SUBJECT: Safety Release for the Helo Transportable Tactical Vehicle (HTTV), TECOM Project Number 1-CO-210-000-047

1. Reference memorandum, USAATC, STEAC-SF-A, dated 31 Oct 97, Subject: Safety Release Recommendation for the Helo Transportable Tactical Vehicle (HTTV), TECOM Project Number 1-CO-210-000-047, enclosed.

2. This memorandum is approved for use as the limited safety release for the user exercise during Nov 97, providing all of the recommendations, stated in the paragraphs 4.0.a., 4.0.b. and 4.0.c. of the referenced document, are adequately addressed through training, hardware modification or operational procedures. In addition, winch operations on either vehicle will not be permitted.

3. All personnel involved in the exercise utilizing the vehicles will read this, and the referenced document, prior to the initiation of vehicle training/operation.

4. Any safety related problems that occur with the vehicles should be forwarded to this office as soon as possible.

Safety Testing of Helo Transportable Tactical Vehicle (HTTV)

Selected automotive performance tests were performed on the Helo Transportable Tactical Vehicle (HTTV) at Aberdeen Test Center by the Vehicles Team from 23 to 29 October 1997. Due to the limited time frame and loss of test time due to a vehicle hardware problem, testing was limited to Tilt Table, Weight Distribution at GVW, and Steering and Handling evaluations.

Specific test results will be provided and discussed in detail in this report. A summary of test results and observations is provided as follows:

a. The gross vehicle weight was 6500 lb as received for test. The payload consisted of a driver, two other crew members (passenger and gunner), uploaded ammunition cans, camouflaged tarp and fuel/water bottles.

b. The static rollover threshold of the vehicle was considered very good. Depending on suspension setting and vehicle orientation on the Tilt Table, the rollover threshold ranged from 0.6 to 0.7 g's.

c. The ability of the vehicle to perform dynamic steering and handling maneuvers such as emergency lane change course negotiation was considered satisfactory. The maximum drive through speed while negotiating the NATO and TOP lane change courses was 80 km/hr and 53 km/hr (50 mph and 33 mph), respectively. The limiting factor was imminent vehicle rollover as wheel liftoff was noted while negotiating the course at the maximum speeds. Although the handling characteristics of the vehicle were considered very good, the high horsepower, low vehicle weight, and narrow width of the vehicle could result in loss of control and/or vehicle rollover if sudden steering maneuvers are made at moderate and high speeds. Operators need to be aware of this and should receive special driver training to include discussion of vehicle operating limits on paved and off-road terrain as well as behind the wheel training before operating this vehicle.

d. While operating at moderate speeds, 30 to 40 mph with the suspension raised, the power steering pump began to cavitate due to air being drawn into the supply line to the pump. The hydraulic fluid reservoir level was noted to be very low with the suspension raised and fluid was contaminated with air bubbles. The reservoir needs to be either enlarged or baffles installed to prevent this condition. It is recommended that until this is modified, operation with the suspension raised should be limited to low speeds only (less than 10 mph) to minimize fluid slosh within the reservoir. It should be noted that prior to performing lane change maneuvers the power steering pump failed and required replacement. The pump failure may have been a result of prior pump cavitation. With the suspension lowered, hydraulic fluid leaked from the reservoir breather due to expansion of the fluid as its temperature increased.

e. When the power steering pump failed, the effort required to steer the vehicle (especially at low speed) and apply the brakes was significantly greater due to the loss of hydraulic assist.

f. There were other Class III hydraulic leaks and coolant leaks which should be corrected as they are both an environmental and fire hazard.

g. When the hood is raised and the engine is operating, the cooling fan blades are considered a safety hazard as the fan shroud provides minimal protection.

Test results are presented as follows.

a. **Physical Dimensions**

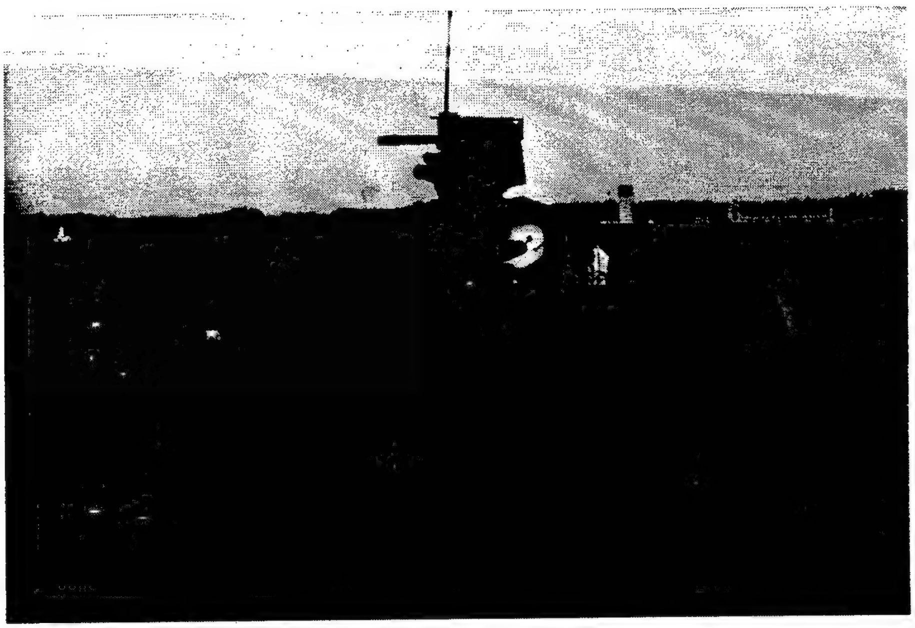


Figure 1. Left front view of the Helo Transportable Tactical Vehicle with full payload, driver and test instrumentation.

Basic physical dimensions of the HTTV were measured using standard mensurative devices such as tape measures, plumb bobs, squares and clinometers. Measurements were made while the vehicle was at GVW with the suspension lowered and raised. Dimensions are presented in Table 1.

TABLE -1. PHYSICAL DIMENSIONS OF THE HELO TRANSPORTABLE TACTICAL VEHICLE (HTTV)

Parameter	**Measured Value**	
	Suspension Lowered	**Suspension Raised**
Length, overall, m (ft)	5.05 (16.55)	5.05 (16.55)
Width, overall, cm (in)	167.6 (66.0)	167.6 (66.0)
Height, overall, cm (in) (top of machine gun)	221.0 (87.0)	230.8 (90.9)
reducible (top of roll cage)	163.0 (64.2)	172.8 (68.0)
Ground clearance, cm (in)		
@ front	30.4 (12.0)	40.4 (15.9)
@ rear	22.2 (8.8)	30.8 (12.1)
Wheelbase, CL of No. 1 to No. 2 , cm (in)	303.0 (119.3)	303.0 (119.3)
Tread, CL of left to right side, cm (in)	132.6 (52.2)	132.6 (52.2)
Pintle height, cm (in)	44.2 (17.4)	52.6 (20.7)
Angle of approach, deg	43	50
Angle of departure, deg	31	35

The center of gravity locations in the longitudinal and lateral planes were determined using the weight distribution method. The center of gravity locations of the HTTV are presented in Table 2.

TABLE 2. CENTER OF GRAVITY LOCATIONS of the HTTV

Directional axis and reference	Distance cm	Distance inches
Longitudinal, forward of no. 2 axle centerline	133.8	52.7
Lateral, left of vehicle centerline	1.2	0.5

b. **Weight Distribution**

The weight distribution at gross vehicle weight (GVW) is presented in Table 3. Individual wheel weights were measured by driving the vehicle across a calibrated platform scale. The vehicle was fully fueled. The payload consisted of a driver, two other crew members (passenger and gunner), uploaded ammunition cans, camouflaged tarp and fuel/water bottles.

TABLE 3. WEIGHT DISTRIBUTION OF HELO TRANSPORTABLE TACTICAL VEHICLE (HTTV) AT GROSS VEHICLE WEIGHT (GVW)

	Left Side		Right Side		Total	
WHEEL	kg	lb	kg	lb	kg	lb
1	640	1420	650	1440	1300	2860
2	860	1900	790	1740	1650	3640
TOTAL	1500	3320	1440	3180	2950	6500

c. **Static Rollover Threshold - Tilt Table**

The rollover threshold of the vehicle at GVW was determined on the ATC Tilt Table on 23 Oct. 97. Tire pressure was adjusted to 30 psi on all tires for all testing. The rollover threshold of the HTTV was considered to be very good. Rollover thresholds are presented in Table 4.

TABLE 4. ROLLOVER THRESHOLDS OF THE HELO TRANSPORTABLE TACTICAL VEHICLE (HTTV) AT GROSS VEHICLE WEIGHT (GVW)

Vehicle Configuration	Wheel Lift-off		Roll-over	
Suspension Lowered:	deg	g's	deg	g's
Left Side Uphill	34.1	0.677	34.1	0.677
Right Side Uphill	34.7	0.692	34.7	0.692
Suspension Raised:				
Left Side Uphill	30.9	0.598	31.2	0.606
Right Side Uphill	33.0	0.649	33.5	0.661

Note that with the suspension lowered, wheel lift-off and rollover occurred at the same time.

Rollover threshold data not only gives an indication of the maximum side slope that the vehicle could negotiate but also provides the maximum lateral acceleration that the vehicle could sustain before experiencing a rollover. The rollover threshold data obtained for this payload configuration indicates that the HTTV should have no trouble negotiating side slopes up to 40% as the static rollover threshold equates to 68 to 69% with the suspension lowered and 61 to 66% with the suspension raised. During sustained high speed cornering with the suspension lowered the HTTV would be able to withstand 0.67 g's before rolling over.

A photographs of the HTTV during Tilt Table testing is enclosed.

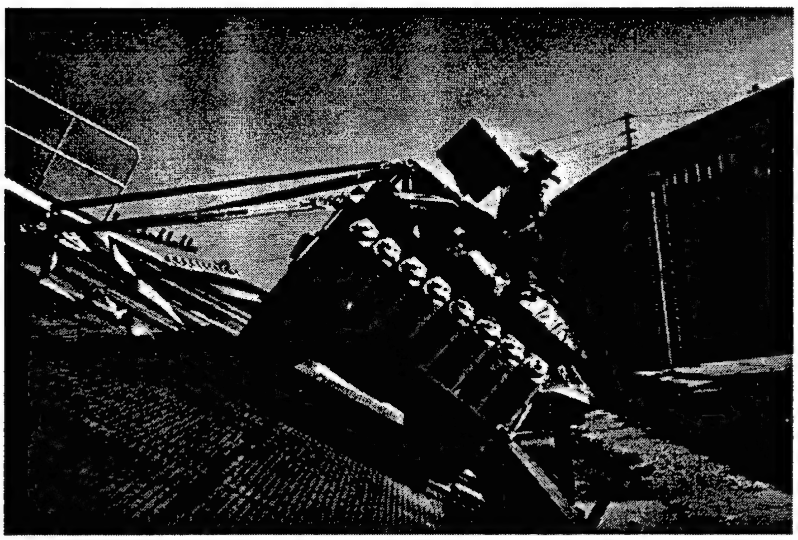
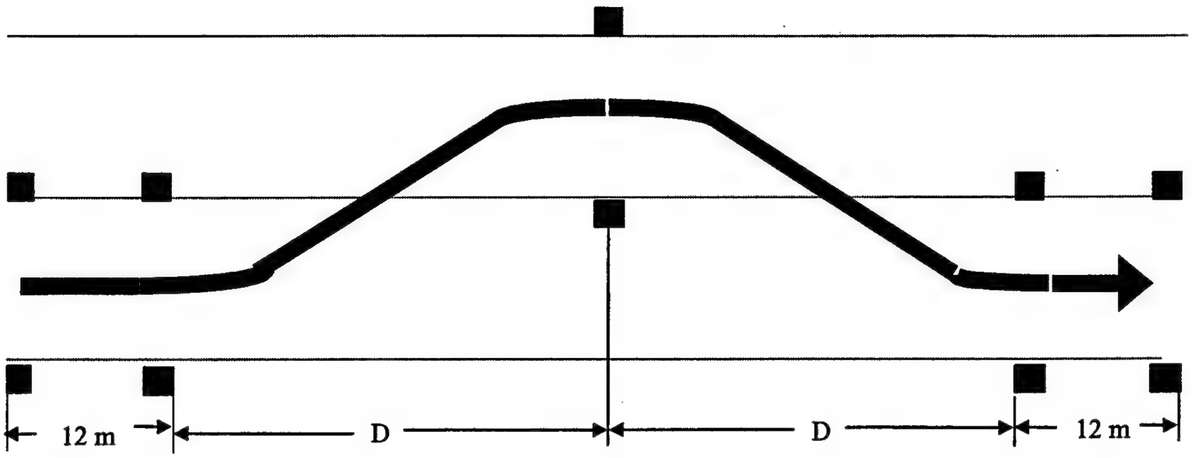


Figure 2. HTTV at rollover threshold. Left side tires have lifted off tilt table and vehicle is restrained by safety straps.

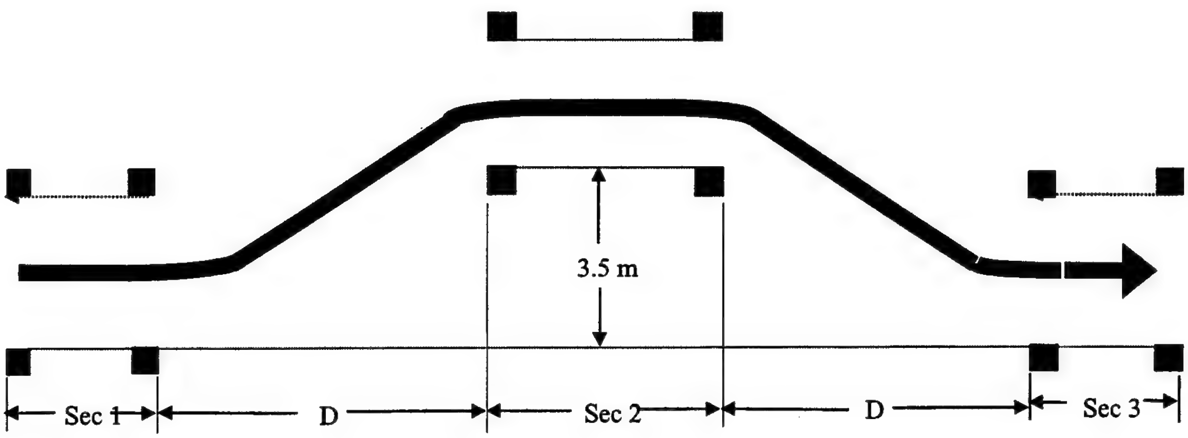
d. **Dynamic Steering Responsiveness Evaluation - Emergency Lane Change Maneuvers.**

The HTTV truck at GVW was operated through two emergency lane change maneuvers. The first course was laid out in accordance with TOP 2-2-002, "Wheeled Vehicle Dynamic Stability and Steering". The second lane change course was laid out in accordance with the NATO AVTP 03-160W "Dynamic Stability" publication. Diagrams showing lane widths and spacing between gates of the two lane change courses are enclosed as figures 1 and 2.



Lane width: 3.7 m (12 ft)
Gate Spacing (D): 18.2 m (59.8 ft) = 1.5 X Minimum Turning Circle Diameter (39.8 ft)

Figure 1. TOP LANE CHANGE COURSE FOR HELO TRANSPORTABLE TACTICAL VEHICLE



Section 1
Lane Width: 271.0 cm (1.6.7 in.) = 1.1 X Vehicle Width + 0.25 m
Lane Length: 15 m (49.2 ft)
Section 2
Lane Width: 293.4 cm (115.5 in.) = 1.2 X Vehicle Width + 0.25 m
Lane Length: 25 m (82.0 ft)
Section 3
Lane Width: 271.0 cm (1.6.7 in.) = 1.1 X Vehicle Width + 0.25 m
Lane Length: 15 m (49.2 ft)
Cone Spacing (D): 33.8 m (110.9 ft) = Effective Length of Vehicle(s) at 0.5 m Above Ground +24 m

Figure 2. AVTP NATO LANE CHANGE COURSE FOR HELO TRANSPORTABLE TACTICAL VEHICLE

The drivers were instructed to negotiate the lane change course as smoothly as possible while staying within the boundaries of the course avoiding the pylons which marked the gates. The initial test runs were made at 40 km/hr (25 mph). Subsequent runs were made at a slightly higher speed until the maximum safe drive-through speed was achieved.

The truck was able to negotiate the NATO lane change course at speeds up to 80 km/hr (50 mph). It was the consensus of all observers that the vehicle was close to reaching its roll instability threshold and that if the driver would have attempted to perform the lane change maneuver at a higher speed loss of control and/or rollover may have occurred. Therefore no additional lane change maneuvers at greater speeds were performed.

The truck was able to negotiate the TOP lane change course at speeds up to 53 km/hr (33 mph). It should be noted that the truck appeared to be nearing its roll stability limit while negotiating this course at 53 km/her (33 mph). Both the right rear and left front wheels raised off the road surface while steering through the second and third gates respectively, therefore no higher speed runs were performed. It should be noted that the distance between gates in the TOP lane change course is determined from the vehicle turning diameter and because the HTTV has such a small turning diameter, the distance between gates was only approximately 60 ft. This was the reason for such a disparity between lane change results.

The limiting factor while negotiating both of these lane change courses was roll stability. During these steering maneuvers two drivers were used with comparable results. Both drivers commented that the steering responsiveness and handling was good. Neither was aware however that wheel lift-off had occurred during the higher speed runs.

Photographs of the vehicle while negotiating the lane change courses are enclosed.

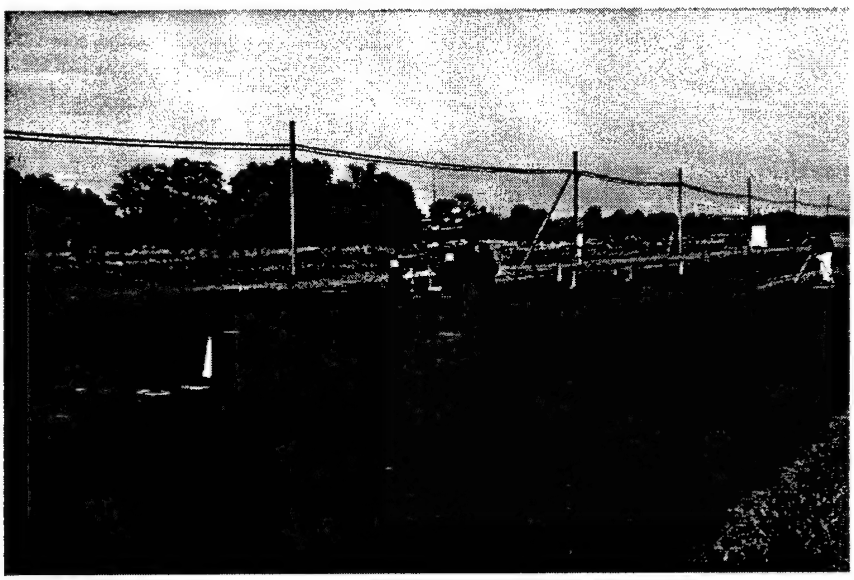


Figure 3. Front view of HTTV transitioning from gate 1 to gate 2 of the TOP lane change course.

Figure 4. Rear view of HTTV transitioning from gate 2 to gate 3 of the TOP lane change course.

e. **Steady-State Steering (Skidpad) Characteristics.**

Reduced steady-state circular test data indicated that the HTTV exhibited primarily understeer handling characteristics through-out the range of lateral accelerations that the vehicle was subjected to during the steady-state, constant radius testing. This is indicated by the predominant negative slope of the handling curves in Figure 3. Understeer occurs when a driver is required to increase his steering input as the vehicle speed increases to maintain a constant radius turn. The front tires of an understeering vehicle exceed their limits of traction before the rear tires exceed their traction limit. An understeering vehicle is inherently directionally stable; that is, the vehicle will tend to continue in a straight line when the traction limit is exceeded.

The steady-state handling characteristics of the vehicle were determined by testing the vehicle in accordance with SAE J2181, "Circular Test Procedure for Trucks and Buses" and NATO Allied Vehicle Testing Publication (AVTP) 03-160W, "Dynamic Stability". Testing was performed on a level, bituminous-concrete circular test course that has a diameter of 60 meters (200 ft). Testing was conducted in both the left and right turn directions, at road speeds ranging from 8 km/hr (5 mph) up to the maximum attainable speed.

For the steering and handling tests (Steady-state steering and lane change testing), the vehicle was instrumented to measure longitudinal and lateral road speeds, steering wheel angle, lateral acceleration, and sprung mass yaw rate.

The limiting factor limiting the maximum attainable speed while performing the steady-state circular test was the driver's feeling of imminent loss of traction and consequential loss of control of the vehicle. Maximum speed was 42.8 and 43.3 km/hr in the left and right steer directions respectively which correlated to a average lateral acceleration of 0.47 and 0.46 g's respectively.

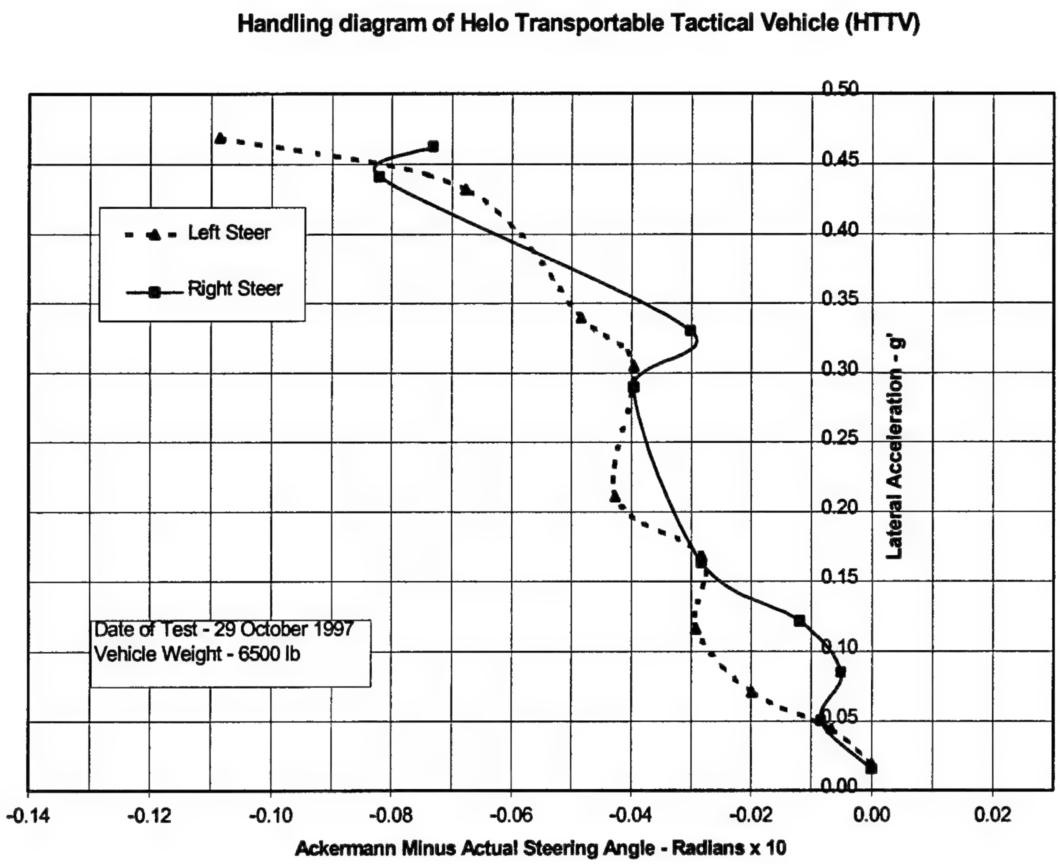


Figure 5. Handling Diagram of the Helo Transportable Tactical Vehicle (HTTV)

Appendix C

Rollover Testing at the Aberdeen Test Center

STEAC-AC-V

MEMORANDUM FOR Aberdeen Center for Sensing Technology,
ATTN: Mr. Donald Lacey

SUBJECT: Report No. 98-VET-(P)-53, ROLL STABILITY TESTS OF THE HELO TRANSPORTABLE TACTICALE VEHICLE (HTTV); TECOM Project No. 1-CO-210-000-048.

1. Enclosed are the test results for selected automotive performance tests conducted to determine the effects of changes in vertical center of gravity versus vehicle track width. Testing included determination of pertinent physical characteristics, weight distribution and center of gravity, turning diameters, tilt table characteristics, emergency lane change capabilities and the steady-state circular test results.

2. Testing was performed with the vehicle in three test configurations between 28 July and 30 November 1998. The first configuration was as the vehicle was initially received without payload. Tests were performed with the vehicle's suspension in the fully lowered and fully raised positions. The second configuration was with the HTTV as initially received but with a 3,000-lb payload. Testing in this configuration was conducted with the front suspension fully lowered and the rear suspension completely raised. The third configuration testing was conducted after modifications were performed by the manufacturer to lower the vehicle's center-of-gravity. All tests were performed without payload with the suspension fully lowered and fully raised. Also tilt table and steady-state circular test procedure testing were performed for the third configuration with the vehicle's suspension canted (one side of the vehicle's suspension fully lowered and the other side fully raised).

3. POC for this project in the Vehicles Team is Charlie Koster, ext 7715.

LYNN W. BERKHEIMER
Chief, Vehicles Team

Encl

1. TESTING AT VEHICLE CURB WEIGHT (VCW)

1.1 Weight Distribution and Center of Gravity

Test Operating Procedure (TOP) 2-2-801 was used as a general guide for weight distribution measurements. The HTTV wheel loads, at VCW, were measured on a calibrated 20,000 lb capacity platform (wheel) scale with an accuracy of ± 0.5% of the reading and a resolution of 2-lb. A total vehicle weight of 2,186 kg (4,820 lb) was measured on a calibrated 200,000 lb capacity platform (vehicle) scale with an accuracy of ± 0.5% of the reading and a resolution of 20-lb.

The HTTV weight distribution, at VCW, (full fuel tank, without driver) with the suspension in the lowered position is presented in Table 1.

TABLE 1. WEIGHT DISTRIBUTION RESULTS
HTTV, AT VCW, SUSPENSION LOWERED

Wheel	Left Side		Right Side		Both Sides	
	kg	lb	kg	lb	kg	lb
1	598	1,318	621	1,368	1,218	2,686
2	477	1,052	485	1,070	963	2,122
Total	1,075	2,370	1,106	2,438	2,181	4,808

The HTTV weight distribution, at VCW, (full fuel tank, without driver) with the suspension in the raised position is presented in Table 2.

TABLE 2. WEIGHT DISTRIBUTION RESULTS
HTTV, AT VCW, SUSPENSION RAISED

Wheel	Left Side		Right Side		Both Sides	
	kg	lb	kg	lb	kg	lb
1	596	1,314	620	1,366	1,216	2,680
2	485	1,070	480	1,058	965	2,128
Total	1,081	2,384	1,100	2,424	2,181	4,808

TOP 2-2-800 was used as a general guide for determining the center of gravity (CG) for the HTTV. The CG was determined in three orthogonal planes. The weight method was used to

determine the CG in the lateral and longitudinal planes and the weight reaction method was used to determine the CG location in the vertical plane.

The HTTV's center of gravity location in three orthogonal orientations, at VCW, in the lowered and raised suspension positions is presented in Table 3.

TABLE 3. CENTER OF GRAVITY, HTTV, AT VCW SUSPENSION LOWERED AND RAISED

Orthogonal Direction	Suspension Position			
	Lowered		Raised	
	Measurement			
	cm	in.	cm	in.
Lateral – right of longitudinal centerline	0.9	0.36	0.5	0.21
Longitudinal – forward of rear axle centerline	169.3	66.65	168.9	66.50
Vertical – above ground	66.0	25.98	78.6	30.94

A vehicle rollover tendency was determined from the following formula:

Rollover Tendency = T/2H (values less than 1.2 are considered unstable)

Where T = track width and H = center of gravity height.

The rollover tendency for the HTTV, at VCW with the suspension lowered was calculated to be 0.98 and 0.82 with the vehicle's suspension in the raised position.

1.2 Physical Characteristics

Pertinent physical dimensions of the HTTV were measured using standard devices such as tape measures, plumb bobs, squares and clinometers. Measurements were made while the vehicle was at VCW with the suspension lowered and raised. The dimensions are presented in Table 4.

TABLE 4. PHYSICAL CHARACTERISTICS, HTTV AT VCW

Parameter	Measured Value	
	Suspension Lowered	Suspension Raised
Length, overall, m (ft)	5.03 (16.5)	5.03 (16.5)
Reducible length, m (ft)	4.77 (15.6)	4.77 (15.6)
Width, overall, cm (in.)	167.4 (65.9)	167.4 (65.9)
Height, ground to roll bar, cm (in.)	164.1 (64.6)	175.5 (69.0)
Wheelbase, CL of No. 1 to No. 2, cm (in.)	303.0 (119.3)	303.0 (119.3)
Tread, CL of left to right side tires, cm (in.)	129.3 (50.9)	129.3 (50.9)
Ground clearance, midpoint between front	29.5 (11.6)	40.6 (16.0)

and rear axles, cm (in.)		
Angle of approach, deg	37.8	45.7
Angle of departure, deg	33.3	38.1

1.3 Steering and Handling

TOP 2-2-609 was used as a general guide for determining the HTTV's cramping angle (steering geometry), steering ratio, and turning diameters.

The HTTV's steering wheel rotated 2 complete turns and 120 degrees from one steering bump stop to the other steering bump stop for a total of 840 degrees. The vehicle's wheel angles at full left and right steer directions with the vehicle at curb weight with the suspension in the lowered and raised position are presented in Table 5.

TABLE 5. STEERING GEOMETERY, HTTV
SUSPENSION LOWERED AND RAISED

Steer Direction	Left Wheel Degree	Right Wheel Degree
Suspension Lowered		
Full left steer	32.0	28.5
Full right steer	29.0	31.0
Suspension Raised		
Full left steer	31.5	28.0
Full right steer	31.5	35.0

The steering ratio calculated from the above data for the suspension in the lowered and raised position was 13.3:1 (13.3 degrees of steering wheel travel to 1 degree of tire travel) and 12.6:1, respectively.

The turning diameter results for the HTTV at VCW with the suspension in the lowered and raised position are presented in Table 6.

TABLE 6. TURNING DIAMETERS, HTTV AT VCW
SUSPENSION LOWERED AND RAISED

Turn Parameter	Left Steer		Right Steer	
	m	ft	m	ft
Suspension Lowered				
Wall-to-wall	15.6	51.3	14.7	48.3
Curb-to curb	14.7	48.3	13.8	45.3
Turning circle	14.4	47.3	13.5	44.3
Inside tire trace	10.0	32.9	9.0	29.6
Suspension Raised				

Wall-to-wall	14.7	48.2	13.7	44.8
Curb-to curb	13.8	45.2	12.7	41.8
Turning circle	13.5	44.2	12.4	40.8
Inside tire trace	9.1	29.8	8.0	26.3

Tilt table testing was performed in accordance with SAE Recommended Practice J2180, "A Tilt Table Procedure for Measuring the Static Rollover Threshold for Heavy Trucks".

Tilt table results for the HTTV at VCW with the suspension in the lowered and raised position are presented in Table 7.

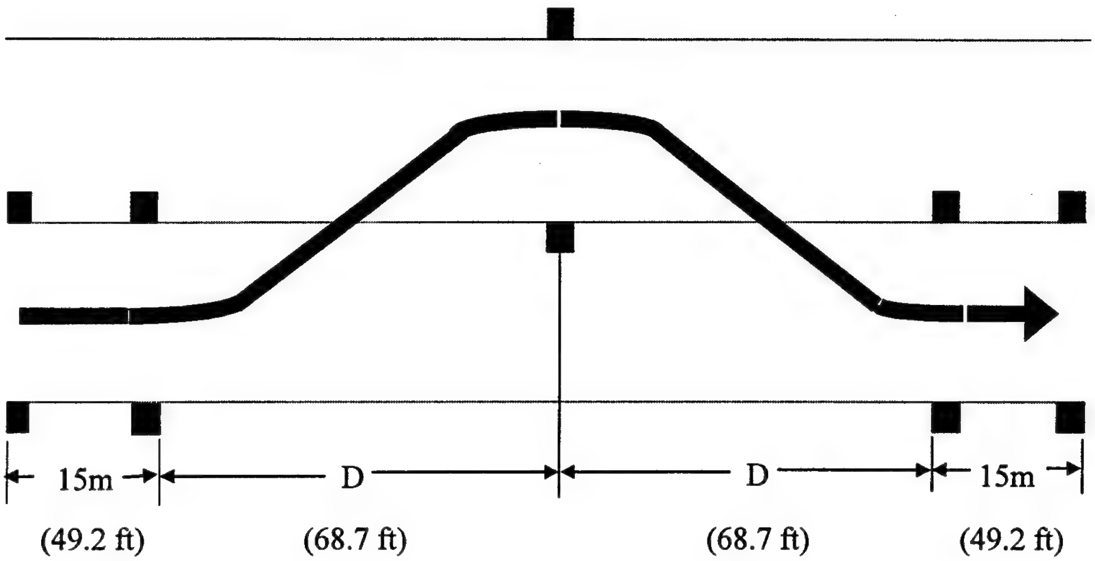
TABLE 7. TILT TABLE RESULTS, HTTV AT VCW SUSPENSION LOWERED AND RAISED		
Wheel #	Wheel Lift-off, Angle Degree's	Simulated Lateral, Acceleration g's
Suspension Lowered - Roadside Upslope		
2	35.7	0.717
1	36.7	0.744
Suspension Lowered - Curbside Upslope		
2	35.8	0.720
1	36.6	0.742
Suspension Raised - Roadside Upslope		
2	34.1	0.676
1	37.7	0.772
Suspension Raised – Curbside Upslope		
2	30.0	0.578
1	37.9	0.778

The HTTV's front and rear axle tire pressures were set to 35 psi.

TOP 2-2-002 was used as a general guide to conduct emergency lane change testing. The HTTV was subjected to two emergency lane change courses. The emergency lane change test course described in AVTP 03-160W (NATO lane change course) and the emergency lane change course described in TOP 2-2-609, with the exception that the lane widths have been limited to 3.6 m (12 ft).

The TOP Emergency Lane Change course layout for the HTTV, at VCW, with the suspension in the lowered position is presented in Figure 1.

TOP LANE CHANGE COURSE FOR THE HTTV AT VCW
SUSPENSION IN LOWERED POSITION



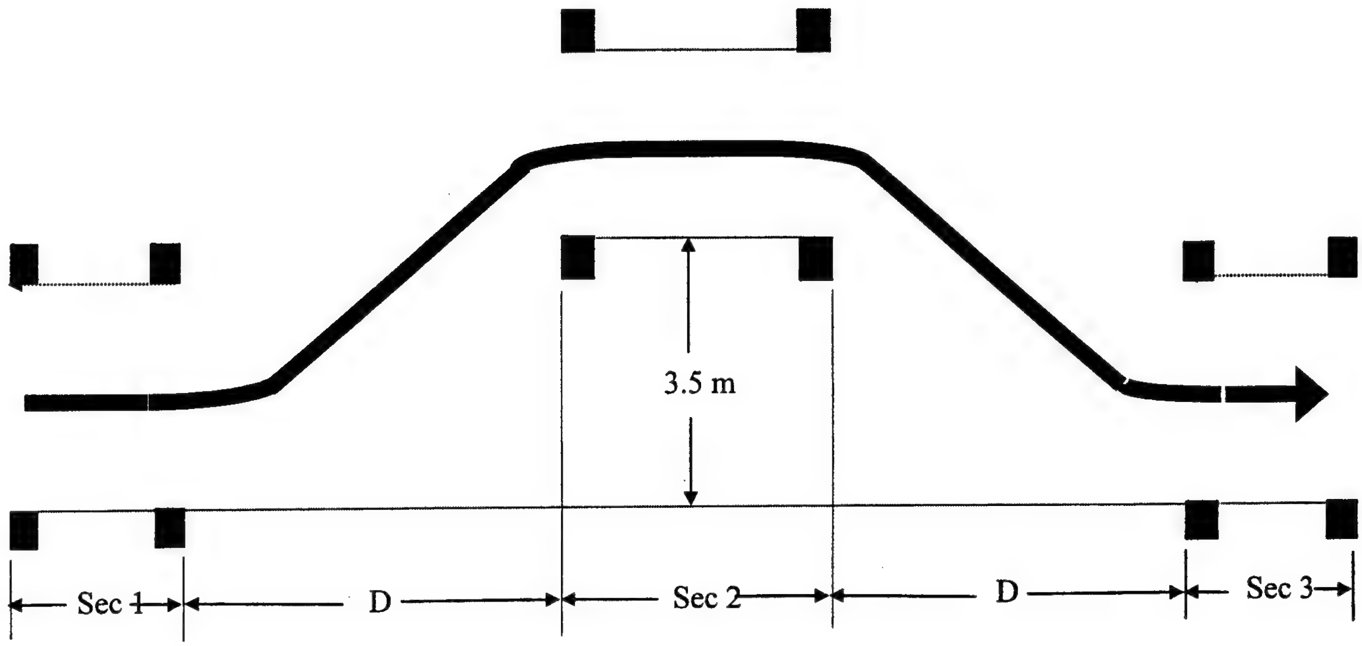
Lane width: 3.7 m (12 ft)
Gate Spacing (D): 20.9 m (68.7 ft) = 1.5 X Average Turning Circle Diameter (45.8 ft)

Figure 1. TOP Lane Change Course used for the HTTV.

The TOP Emergency Lane Change course distance between the gates (D) was reduced by 4.9 ft to a distance of 63.8 ft for the HTTV, at VCW, with the suspension in the raised position because of the reduced average turning diameter measured in the raised suspension position.

The NATO Emergency Lane Change course layout is presented in Figure 2. The course dimensions are the same for the HTTV in both the lowered and raised suspension positions.

NATO LANE CHANGE COURSE FOR THE HTTV



Section 1
Lane Width: 2.03 m (6.7 ft) = 1.1 X Vehicle Width + 0.25 m
Lane Length: 15 m (49.2 ft)
Section 2
Lane Width: 2.19 m (7.2 ft) = 1.2 X Vehicle Width + 0.25 m
Lane Length: 25 m (82.0 ft)
Section 3
Lane Width: 2.03 m (6.7 ft) = 1.1 X Vehicle Width + 0.25 m
Lane Length: 15 m (49.2 ft)
Cone Spacing (D): 27.89 m (91.5 ft) = Effective Length of Vehicle at 0.5 m Above Ground +24 m.

Figure 2. NATO Lane Change Course used for the HTTV.

The HTTV successfully negotiated the TOP lane change course, at VCW with the suspension in the lowered position at a nominal road speed of 66.5 km/hr (41.3 mph). Testing was suspended at this nominal road speed because the vehicle's right rear wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.80 g's. The HTTV successfully negotiated the TOP lane change course, at VCW with the suspension in the raised position at a nominal road speed of 60.3 km/hr (37.5 mph). Testing was suspended at this nominal road speed because the vehicle's right rear wheel was lifting

off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.78 g's.

The HTTV successfully negotiated the NATO lane change course, at VCW with the suspension in the lowered position at a nominal road speed of 78.2 km/hr (48.6 mph). Testing was suspended at this nominal road speed because the vehicle's right rear wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.75 g's. The HTTV successfully negotiated the NATO lane change course, at VCW with the suspension in the raised position at a nominal road speed of 73.8 km/hr (45.9 mph). Testing was suspended at this nominal road speed because the vehicle's right rear wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.71 g's.

The steady-state cornering characteristics of the HTTV were determined using SAE J2181, Steady State Circular Test Procedure for Trucks and Buses. The HTTV was operated at a constant road speed around a bituminous-concrete circular test course having a nominal diameter of 61 meters (200 ft). Testing was performed in both the left and right steer directions, at VCW with the vehicle's suspension in the lowered and raised position, at road speeds ranging from 8 km/hr (5 mph) up to the maximum attainable safe speed.

A handling diagram was produced for the HTTV using the data obtained during constant radius turn testing. A handling diagram shows the relationship of vehicle steering angle to its lateral acceleration. By examining the local slope of the curve on the diagram, it can be determined whether the vehicle understeers, oversteers, or exhibits neutral steer characteristics at a given level of lateral acceleration. A negative slope indicates that a vehicle is in an understeering condition, while a positive slope indicates that the vehicle is in an oversteering condition. An infinite (vertical) slope indicates that the vehicle is in a neutral steering condition and may also determine the point at which the vehicle is in transition from one steering condition to the other.

The HTTV, at curb weight, with the suspension lowered and raised demonstrated understeer handling characteristics throughout the lateral acceleration range achieved during constant radius turn ("skidpad") testing in both the clockwise (CW) steer direction and the counter-clockwise steer direction. The HTTV at VCW, with its suspension in the lowered position, achieved a lateral acceleration of 0.56 g's, at the road surface, in the left (CCW) steer direction, and 0.48 g's in the right (CW) steer direction. Testing in each direction was suspended when the rear wheel lifted off the road surface. The HTTV at VCW, with its suspension in the raised position, achieved a lateral acceleration of 0.51 g's, at the road surface, in the left (CCW) steer direction, and 0.45 g's in the right (CW) steer direction. Testing in each direction was suspended when the rear wheel lifted off the road surface.

Constant radius turn test results for the HTTV, at VCW, with the suspension lowered and raised are presented in handling diagram form in Figures 3 and 4, respectively.

The tendency of the HTTV, at VCW to exhibit an understeer handling behavior as cornering forces increase is considered to be a desirable handling trait. To maximize safety and controllability, it is highly desirable for vehicles to understeer at all levels of lateral acceleration. An understeering vehicle is inherently directionally stable; that is, the vehicle will tend to continue in a straight line when the traction limit is exceeded. Conversely, an oversteering vehicle tends toward directional instability; the vehicle tends to tighten its turn when the traction limit is exceeded.

In addition to its inherent directional stability, an understeering vehicle is also more easily controlled by the average driver. An understeering vehicle will follow a wider turn arc than was expected by the driver. To recover an understeering vehicle that has exceeded its limit of traction, the driver should reduce the throttle, apply brakes, and/or increase the steering wheel angle. All of these corrective actions are instinctive for even the most inexperienced drivers, and therefore an understeering vehicle is "forgiving" to driver errors. In contrast, an oversteering vehicle will turn tighter than the driver expected. Therefore to recover an oversteering vehicle that has exceeded its traction capability, the driver should apply throttle and/or reduce the steering wheel angle; these actions are alien to normal human reactions, and can only be learned through experience.

2. HTTV TESTING WITH 3000 LB PAYLOAD

Note: All tests performed by the HTTV with the 3000 lb payload were conducted with the front suspension fully lowered and the rear suspension fully raised.

2.1 Weight Distribution and Center of Gravity

The payloaded HTTV weight distribution (driver's weight simulated) is presented in Table 8.

TABLE 8. WEIGHT DISTRIBUTION RESULTS
PAYLOADED HTTV

Wheel	Left Side		Right Side		Both Sides	
	kg	lb	kg	lb	kg	lb
1	688	1,516	744	1,640	1,432	3,156
2	1,027	2,264	1,089	2,400	2,115	4,664
Total	1,715	3,780	1,833	4,040	3,547	7,820

The HTTV's payloaded center of gravity location in three orthogonal orientations is presented in Table 9.

TABLE 9. CENTER OF GRAVITY, HTTV PAYLOADED
FRONT SUSPENSION LOWERED, REAR SUSPENSION RAISED

Orthogonal Direction	Measurement	
	cm	in.
Lateral – right of longitudinal centerline	2.1	0.83
Longitudinal – forward of rear axle centerline	122.3	48.15
Vertical – above ground	74.5	29.33

The calculated rollover tendency for the payloaded HTTV was 0.87.

2.2 Steering and Handling

The HTTV's cramping angles were measured with the HTTV in the payloaded test condition. The vehicle's wheel angles at full left and right steer directions are presented in Table 10.

TABLE 10. STEERING GEOMETERY, HTTV PAYLOADED TEST CONDITION

Steer Direction	Left Wheel	Right Wheel
	Degree	Degree
Full left steer	30.0	26.0
Full right steer	30.0	32.0

The steering ratio calculated for the payloaded HTTV from the above data with the suspension lowered in the front and raised in the rear was 13.5:1 (13.5 degrees of steering wheel travel to 1 degree of tire travel).

The turning diameter results for the payloaded HTTV are presented in Table 11.

TABLE 11. TURNING DIAMETERS, HTTV PAYLOADED

Turn Parameter	Left Steer		Right Steer	
	m	ft	m	ft
Wall-to-wall	15.6	51.3	14.5	47.6
Curb-to curb	14.7	48.3	13.6	44.6
Turning circle	14.4	47.3	13.3	43.6
Inside tire trace	10.5	34.3	9.3	30.5

Tilt table results for the payloaded HTTV are presented in Table 12.

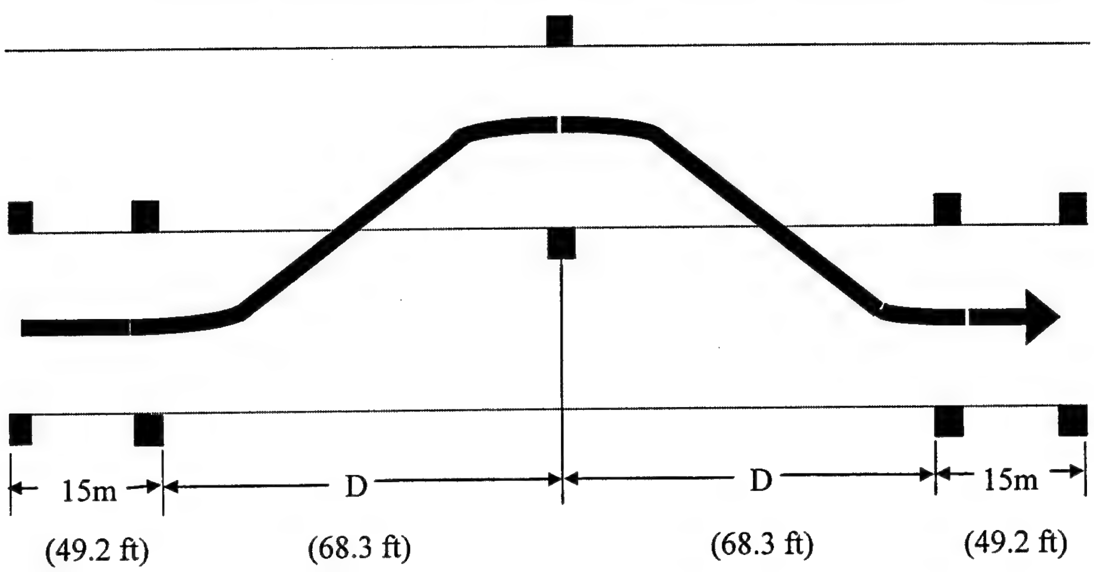
TABLE 12. TILT TABLE RESULTS, HTTV PAYLOADED

Wheel #	Wheel Lift-off, Angle Degree's	Simulated Lateral, Acceleration g's
Roadside Upslope		
2	31.7	0.617
1	31.7	0.617
Curbside Upslope		
2	33.2	0.655
1	33.2	0.655

The HTTV's front and rear axle tire pressures were set to 35 psi.

The TOP Emergency Lane Change course layout for the payloaded HTTV is presented in Figure 5.

TOP LANE CHANGE COURSE FOR THE PAYLOADED HTTV
FRONT SUSPENSION LOWERED – REAR SUSPENSION RAISED



Lane width: 3.7 m (12 ft)
Gate Spacing (D): 20.8 m (68.3 ft) = 1.5 X Minimum Turning Circle Diameter (45.5 ft)

Figure 5. TOP Lane Change Course used for the payloaded HTTV.

The NATO lane change course dimensions for the payloaded HTTV are the same as for the HTTV at VCW.

The payloaded HTTV successfully negotiated the TOP lane change course at a nominal road speed of 53.3 km/hr (33.1 mph). Testing was suspended at this nominal road speed because the

vehicle's right front wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.66 g's.

The payloaded HTTV successfully negotiated the NATO lane change course at a nominal road speed of 68.0 km/hr (42.3 mph). Testing was suspended at this nominal road speed because the vehicle's right front wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.59 g's.

Steady State Circular Test Procedure was performed by the HTTV, at GVW with the front suspension fully lowered and the rear suspension fully raised. A handling diagram was produced for the HTTV using the data obtained during the constant radius turn testing. The HTTV, at GVW, demonstrated essentially neutral handling characteristics throughout the lateral acceleration range achieved in both the CW and CCW steer directions until a lateral acceleration of approximately 0.4 g's, at which point the steering behavior becomes oversteer in nature. The HTTV, at GVW, achieved a lateral acceleration of 0.42 g's, at the road surface, in the left (CCW) steer direction, and 0.47 g's in the right (CW) steer direction.

Constant radius turn test results for the HTTV, at GVW, are presented in handling diagram form in Figure 6.

3. TESTING AT VEHICLE CURB WEIGHT AFTER MODIFICATIONS

3.1 Weight Distribution and Center of Gravity

The HTTV wheel loads were measured on a calibrated 20,000 lb capacity platform (wheel) scale with an accuracy of ± 0.5% of the reading and a resolution of 2-lb. The wheel loads were rounded to the nearest 5-kg (10-lb).

The HTTV weight distribution, at VCW, (full fuel tank, with test instrumentation, without driver) with the suspension in the lowered position is presented in Table 13.

TABLE 13. WEIGHT DISTRIBUTION RESULTS
HTTV, AT VCW, SUSPENSION LOWERED

Wheel	Left Side		Right Side		Both Sides	
	kg	lb	kg	lb	kg	lb
1	590	1,300	610	1,350	1,200	2,650
2	505	1,110	495	1,090	1,000	2,200
Total	1,095	2,410	1,105	2,440	2,200	4,850

The HTTV weight distribution, at VCW, (full fuel tank, with test instrumentation, without driver) with the suspension in the raised position is presented in Table 14.

TABLE 14. WEIGHT DISTRIBUTION RESULTS HTTV, AT VCW, SUSPENSION RAISED						
	Left Side		Right Side		Both Sides	
Wheel	kg	lb	kg	lb	kg	lb
1	590	1,300	620	1,370	1,210	2,670
2	500	1,100	490	1,080	990	2,180
Total	1,090	2,400	1,110	2,450	2,200	4,850

The HTTV weight distribution, at VCW, (full fuel tank, with test instrumentation, without driver) with the right side of the vehicle's suspension in the raised position and the left side of the vehicle in the lowered position is presented in Table 15.

TABLE 15. WEIGHT DISTRIBUTION RESULTS HTTV, AT VCW, RIGHT SIDE RAISED/LEFT SIDE LOWERED						
	Left Side		Right Side		Both Sides	
Wheel	kg	lb	kg	lb	kg	lb
1	505	1,110	685	1,510	1,190	2,620
2	590	1,300	420	930	1,010	2,230
Total	1,0950	2,410	1,105	2,440	2,200	4,850

The HTTV weight distribution, at VCW, (full fuel tank, with test instrumentation, without driver) with the right side of the vehicle's suspension in the lowered position and the left side of the vehicle in the raised position is presented in Table 16.

TABLE 16. WEIGHT DISTRIBUTION RESULTS HTTV, AT VCW, RIGHT SIDE LOWERED/LEFT SIDE RAISED						
	Left Side		Right Side		Both Sides	
Wheel	kg	lb	kg	lb	kg	lb
1	680	1,500	505	1,110	1,185	2,610
2	395	870	620	1,370	1,015	2,240
Total	1,075	2,370	1,125	2,480	2,200	4,850

The HTTV's center of gravity location in three orthogonal orientations, at VCW, in the lowered and raised suspension positions is presented in Table 17.

TABLE 17. CENTER OF GRAVITY, HTTV, AT VCW
SUSPENSION LOWERED AND RAISED AFTER MODIFICATIONS

Orthogonal Direction	Suspension Position			
	Lowered		Raised	
	Center of Gravity Measurement			
	cm	in.	cm	in.
Lateral – right of longitudinal centerline	0.4	0.2	0.7	0.3
Longitudinal – forward of rear axle centerline	165.6	65.2	166.8	65.7
Vertical – above ground	51.6	20.3	64.5	25.4

The calculated rollover tendency value for the HTTV, at VCW, after modifications with the vehicle suspension in the lowered and raised positions are 1.27 and 1.02, respectively.

The HTTV's center of gravity locations in three orthogonal orientations, at VCW, in the canted suspension positions are presented in Table 18.

TABLE 18. CENTER OF GRAVITY, HTTV, AT VCW
LEFT SIDE LOWERED/RIGHT SIDE RAISED AND
LEFT SIDE RAISED/RIGHT SIDE LOWERED

Orthogonal Direction	Suspension Position			
	Lt Low/Rt Up		Lt Up/Rt Low	
	Measurement			
	cm	in.	cm	in.
Lateral – right of longitudinal centerline	0.4	0.2	1.5	0.6
Longitudinal – forward of rear axle centerline	163.7	64.4	163.1	64.2
Vertical – above ground	66.2	26.1	62.5	24.6

3.2 Physical Characteristics

Pertinent physical dimensions of the HTTV were measured using standard devices such as tape measures, plumb bobs, squares and clinometers. Measurements were made while the vehicle was at VCW with the suspension lowered and raised. The dimensions are presented in Table 19.

TABLE 19. PHYSICAL CHARACTERISTICS, HTTV AT VCW

Parameter	Measured Value	
	Suspension Lowered	Suspension Raised
Length, overall, m (ft)	5.03 (16.5)	5.03 (16.5)
Reducible Length, m (ft)	4.77 (15.6)	4.77 (15.6)
Width, overall, cm (in.)	167.4 (65.9)	167.4 (65.9)
Height, ground to roll bar, cm (in.)	154.0 (60.6)	165.0 (65.0)

Wheelbase, CL of No. 1 to No. 2, cm (in.)	303.0 (119.3)	303.0 (119.3)
Tread, CL of left to right side, cm (in.)	131.0 (51.6)	131.0 (51.6)
Ground clearance, midpoint between front and rear axles, cm (in.)	18.2 (7.2)	28.5 (11.2)
Angle of approach, deg	33.4	39.8
Angle of departure, deg	32.6	42.1

TOP 2-2-801 was used as a general guide for determining ground pressure measurements.

Ground pressure measurements were determined for the HTTV with the vehicle's suspension in the lowered position. The results are presented in Table 20.

TABLE 20. HTTV GROUND PRESSURE RESULTS, AT VCW, SUSPENSION LOWERED

	Specific Ground Pressure		Nominal Ground Pressure	
Wheel location	kPa	psi	kPa	psi
Left front	455.4	66.0	184.2	26.7
Right front	487.8	70.7	191.1	27.7
Left rear	437.5	63.4	207.7	30.1
Right rear	431.9	62.6	179.4	26.0

3.3 Steering and Handling at VCW

The HTTV's steering wheel rotated 2 complete turns and 120 degrees from one steering bump stop to the other steering bump stop for a total of 840 degrees. The vehicle's wheel angles at full left and right steer directions with the vehicle at curb weight with the suspension in the lowered and raised position are presented in Table 21.

TABLE 21. STEERING GEOMETERY, HTTV SUSPENSION LOWERED AND RAISED

	Left Wheel	Right Wheel
Steer Direction	Degree	Degree
Suspension Lowered		
Full left steer	26.0	23.5
Full right steer	29.0	32.0
Suspension Raised		
Full left steer	28.0	25.5
Full right steer	31.5	35.0

The steering ratio calculated from the above data for the suspension in the lowered and raised position was 14.5:1 (14.5 degrees of steering wheel travel to 1 degree of tire travel) and 13.3:1, respectively.

The turning diameter results for the HTTV at VCW with the suspension in the lowered and raised position are presented in Table 22.

TABLE 22. TURNING DIAMETERS, HTTV AT VCW SUSPENSION LOWERED AND RAISED

Turn Parameter	Left Steer		Right Steer	
	m	ft	m	ft
Suspension Lowered				
Wall-to-wall	16.8	55.1	15.5	50.8
Curb-to curb	15.9	52.1	14.6	47.8
Turning circle	15.6	51.1	14.3	46.8
Inside tire trace	11.5	37.6	10.1	33.3
Suspension Raised				
Wall-to-wall	16.1	52.7	14.5	47.7
Curb-to curb	15.1	49.7	13.6	44.7
Turning circle	14.8	48.7	13.3	43.7
Inside tire trace	10.4	34.2	9.1	29.9

Tilt table results for the HTTV at VCW with its suspension in the lowered, raised, and canted positions are presented in Table 23.

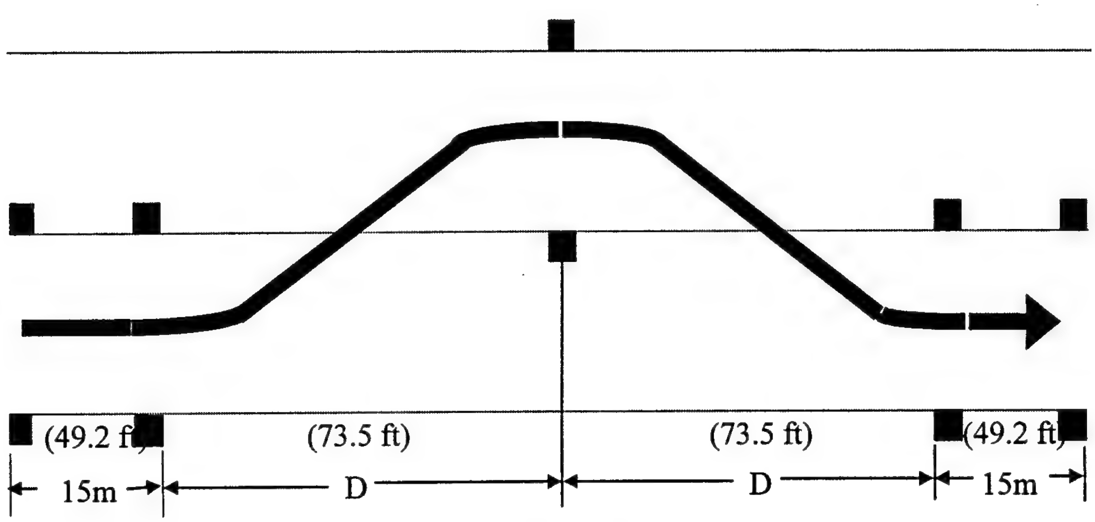
TABLE 23. TILT TABLE RESULTS, HTTV AT VCW SUSPENSION LOWERED, RAISED, AND CANTED

Wheel #	Wheel Lift-off, Angle Degree's	Simulated Lateral, Acceleration g's
Suspension Lowered - Roadside Upslope		
2	39.7	0.829
1	Still on Table	
Suspension Lowered - Curbside Upslope		
2	39.7	0.829

1	Still on Table	
Suspension Raised - Roadside Upslope		
2	35.0	0.700
1	38.8	0.805
Suspension Raised – Curbside Upslope		
2	34.9	0.698
1	38.2	0.787
Downslope Side Raised – Upslope Side Lowered		
Roadside Upslope		
2	38.8	0.804
1	38.8	0.804
Curbside Upslope		
2	39.1	0.812
1	39.1	0.812

The TOP Emergency Lane Change course layout for the HTTV, at VCW, with the suspension in the lowered position is presented in Figure 7.

TOP LANE CHANGE COURSE FOR THE HTTV AT VCW
SUSPENSION IN LOWERED POSITION



Lane width: 3.7 m (12 ft)
Gate Spacing (D): 22.4 m (73.5 ft) = 1.5 X Average Turning Circle Diameter (49.0 ft)

Figure 7. TOP Lane Change Course used for the HTTV.

The TOP Emergency Lane Change course distance between the gates (D) was reduced by 4.2 ft to a distance of 69.3 ft for the HTTV, at VCW, with the suspension in the raised position because of the reduced turning diameter measured in the raised suspension position.

The NATO Emergency Lane Change course layout for the HTTV with its suspension in the lowered and raised position is the same as presented in Figure 2.

The HTTV successfully negotiated the TOP lane change course, at VCW with the suspension in the lowered position at a nominal road speed of 69.1 km/hr (42.9 mph). Testing was suspended at this nominal road speed because the vehicle's right rear wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.90 g's. The HTTV successfully negotiated the TOP lane change course, at VCW with the suspension in the raised position at a nominal road speed of 67.1 km/hr (41.7 mph). Testing was suspended at this nominal road speed because the vehicle's right rear wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.78 g's.

The HTTV successfully negotiated the NATO lane change course, at VCW with the suspension in the lowered position at a nominal road speed of 76.7 km/hr (47.7 mph). Testing was suspended at this nominal road speed because the vehicle's right rear wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.92 g's. The HTTV successfully negotiated the NATO lane change course, at VCW with the suspension in the raised position at a nominal road speed of 71.6 km/hr (44.5 mph). Testing was suspended at this nominal road speed because the vehicle's right rear wheel was lifting off the road surface. A lateral accelerometer mounted at the vehicle's center of gravity measured a peak lateral acceleration of 0.88 g's (with wheel lift off - 0.73 g's without wheel lift off while negotiating the course).

The steady-state cornering characteristics of the HTTV were determined using SAE J2181, Steady State Circular Test Procedure for Trucks and Buses. The HTTV was operated at a constant road speed around a bituminous-concrete circular test course having a nominal diameter of 61 meters (200 ft). Testing was performed in both the left and right steer directions with the vehicle's suspension in the lowered and raised positions. Testing was also performed with the vehicle's suspension set such that the outer side of the vehicle was raised and the inner side of the vehicle was lowered as the vehicle negotiated the skidpad course. Road speeds ranged from 8 km/hr (5 mph) up to the maximum attainable safe speed.

A handling diagram developed from the circular test procedure data for the HTTV at VCW, with its suspension in the lowered position is presented in Figure 8. The vehicle achieved a lateral acceleration of 0.63 g's, at the road surface, in the left (CCW) steer direction, and 0.64 g's in the right (CW) steer direction. Testing in each direction was suspended when the rear wheel lifted off the road surface. The HTTV demonstrated predominately understeer handling characteristics throughout the entire lateral acceleration range in the CW direction. In the CCW direction the vehicle indicated understeer handling traits from very low levels of lateral acceleration up to approximately 0.24 g's. The vehicle then demonstrated neutral steering behavior from 0.24 g's up to approximately 0.48 g's of lateral acceleration, from which point steer was oversteer in nature up to the maximum level of lateral acceleration achieved.

A handling diagram developed from the circular test procedure data for the HTTV at VCW, with its suspension in the raised position is presented in Figure 9. The vehicle achieved a lateral acceleration of 0.61 g's, at the road surface, in the left (CCW) steer direction, and 0.60 g's in the right (CW) steer direction. Testing in each direction was suspended when the rear wheel lifted off the road surface. The HTTV's handling characteristics throughout the entire lateral acceleration range in the CW direction were also predominately understeer as with its suspension lowered. In the CCW direction the vehicle indicated understeer handling traits from very low levels of lateral acceleration up to approximately 0.24 g's at which point the vehicle's handling behavior transitioned to oversteer and remained oversteer in nature until a lateral acceleration of approximately 0.40 g's. The vehicle then demonstrated neutral steering behavior from 0.40 g's up to the maximum level of lateral acceleration achieved.

The HTTV, at curb weight, with the suspension set with the inner side of the vehicle lowered and the outer side raised demonstrated understeer handling characteristics throughout the lateral acceleration range achieved during constant radius turn ("skidpad") testing in the CW steer direction. In the counter-clockwise turn direction the vehicle's steering behavior was understeer throughout the lateral acceleration range except for a brief neutral steer period between 0.24 and 0.30 g's. The HTTV at VCW, with its suspension in this configuration achieved a lateral acceleration of 0.63 g's, at the road surface, in the left (CCW) steer direction. The highest level of lateral acceleration recorded in the CW steer direction was 0.60 g's. A higher level of lateral acceleration was achieved, however, the driver suspended the test run due to wheel lift before sufficient data was recorded. The vehicle's handling diagram for this test condition is presented in Figure 10.

The canted suspension position did improve the HTTV's steering characteristics during the steady state circular test procedure, demonstrating understeer-handling behavior in both the left and right steer directions. But it did not make any significant improvement in increased lateral stability as indicated by the tilt table results and the road speed at which wheel lift off was experienced during the circular test procedure.

The undesirable handling characteristics demonstrated in the CCW steer direction with the vehicle's suspension in the lowered and the raised position may have been caused by an improper front-end alignment. The HTTV's (with the suspension lowered) right front wheel's camber angle was measured to be 6 degrees, and its left front wheel's camber angle was measured to be 3 degrees. The vehicle's toe was measured to be 1.85 inches (toe-in).

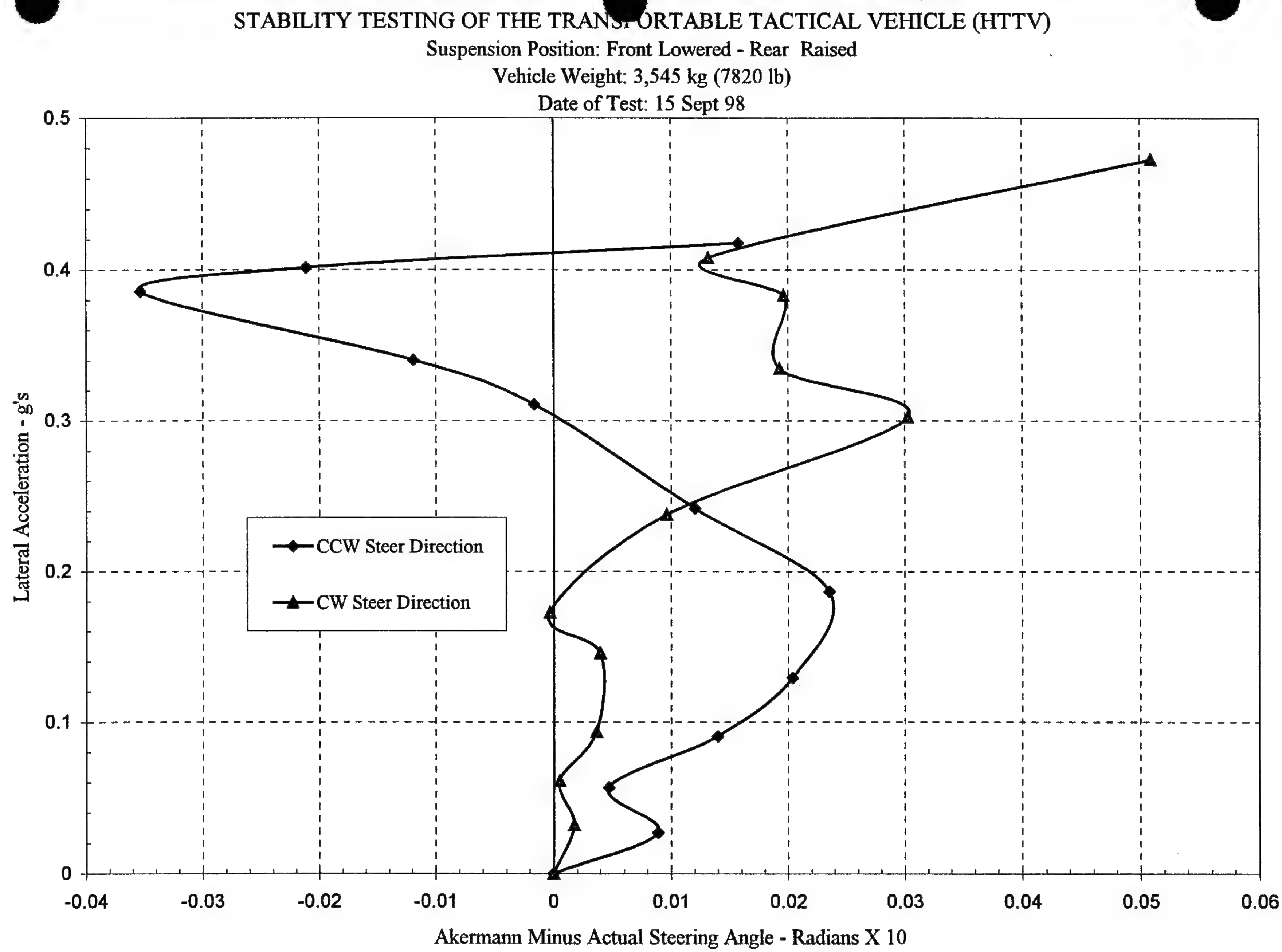


Figure 6. Handling Diagram for the HTTV, at GVW, with the vehicle's front suspension lowered and its rear suspension raised.

STABILITY TESTING OF THE HELO TRANSPORTABLE TACTICAL VEHICLE (HTTV)
Suspension Position: Lowered
Vehicle Weight: 2,185 kg (4820 lb)
Date of Test: 10 Sept 98

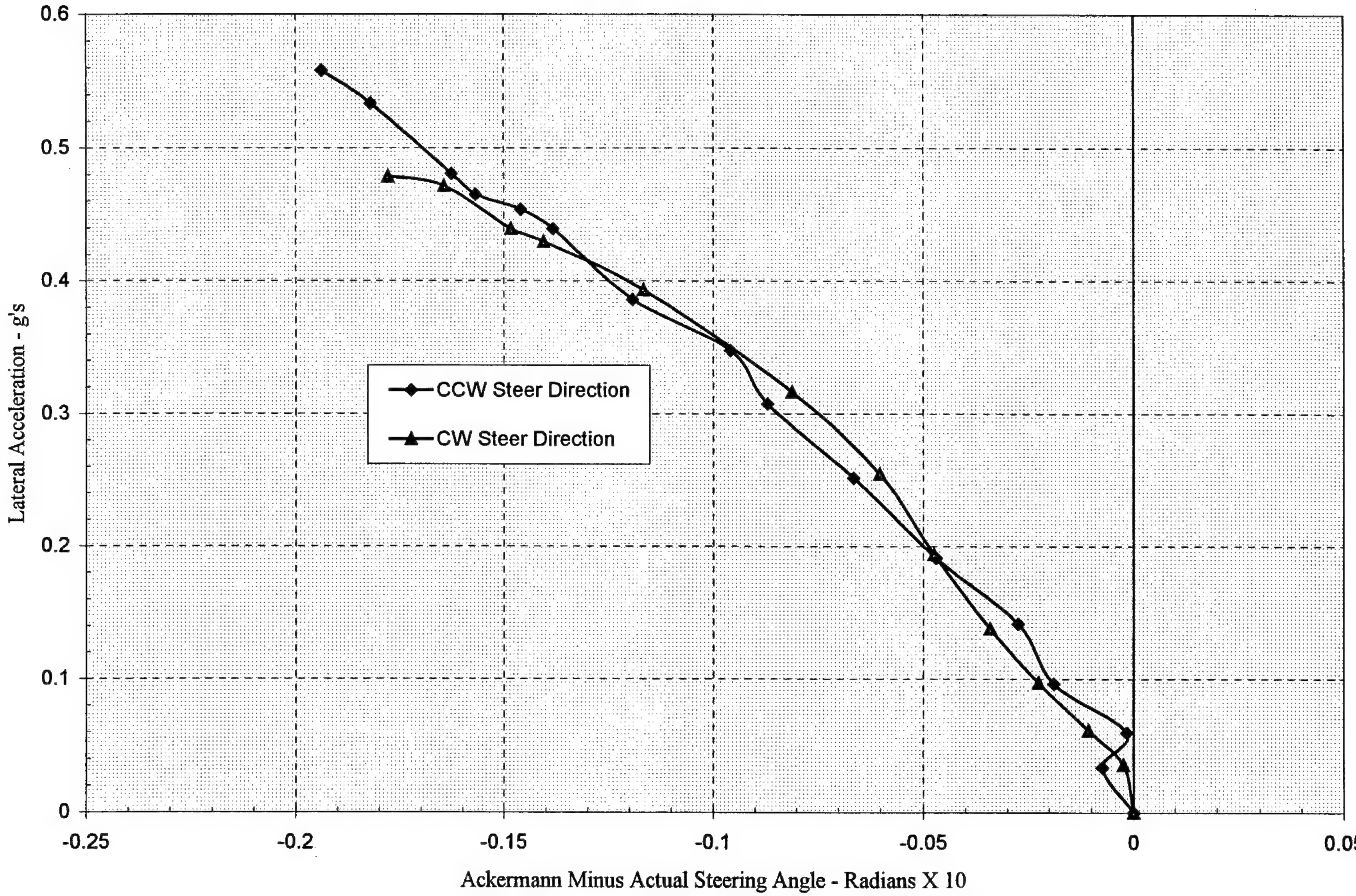


Figure 3. Handling Diagram for the HTTV, at VCW, with the vehicle suspension in the lowered position, negotiating 30 m turn radius.

STABILITY TESTING OF THE HELO TRANSPORTABLE TACTICAL VEHICLE (HTTV)

Suspension Position: Raised

Vehicle Weight: 2,230 kg (4920 lb)

Date of Test: 29 Oct 98

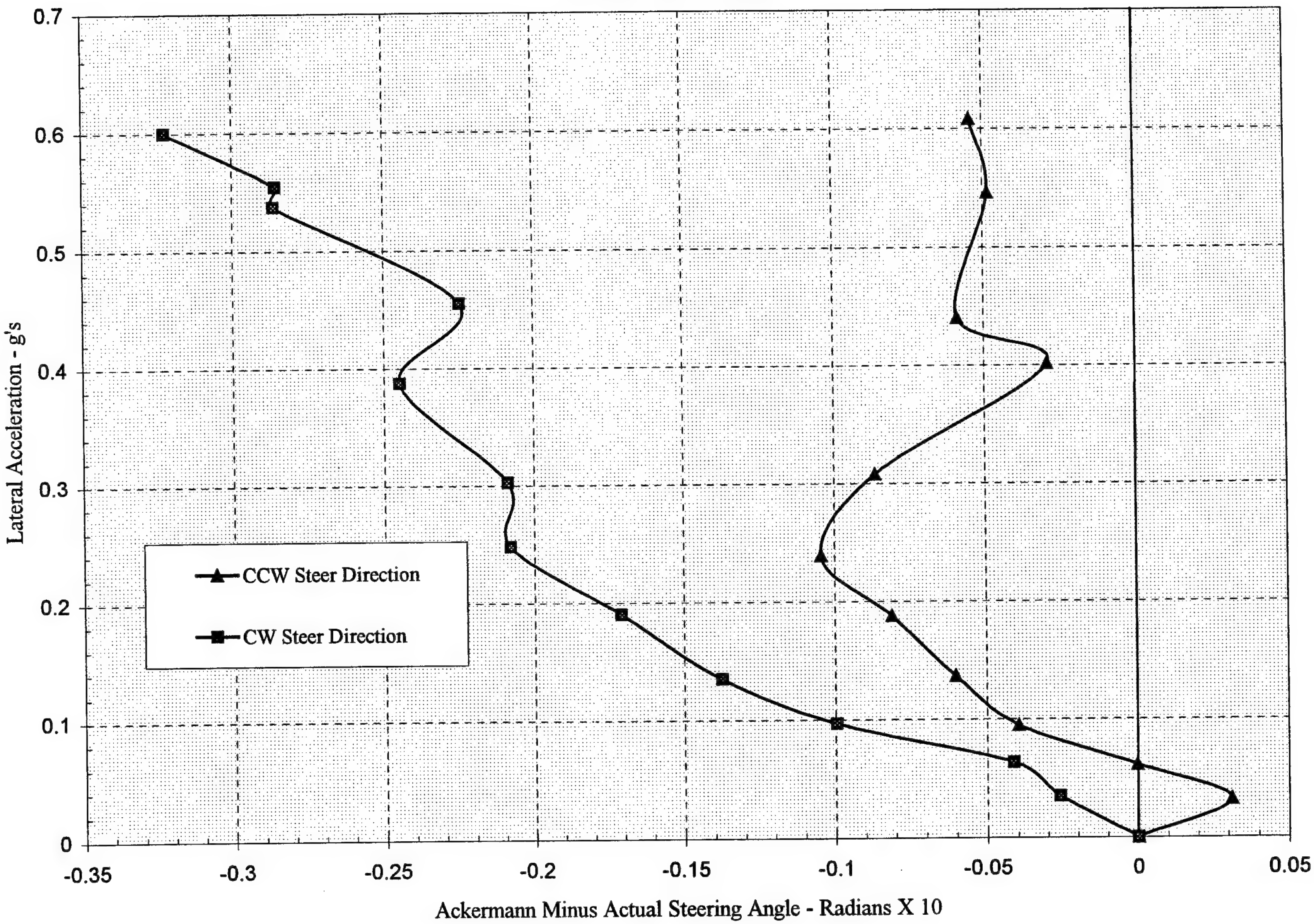


Figure 9. Handling Diagram for the HTTV, at VCW, with the vehicle suspension in the raised position, negotiating 30 m turn radius.

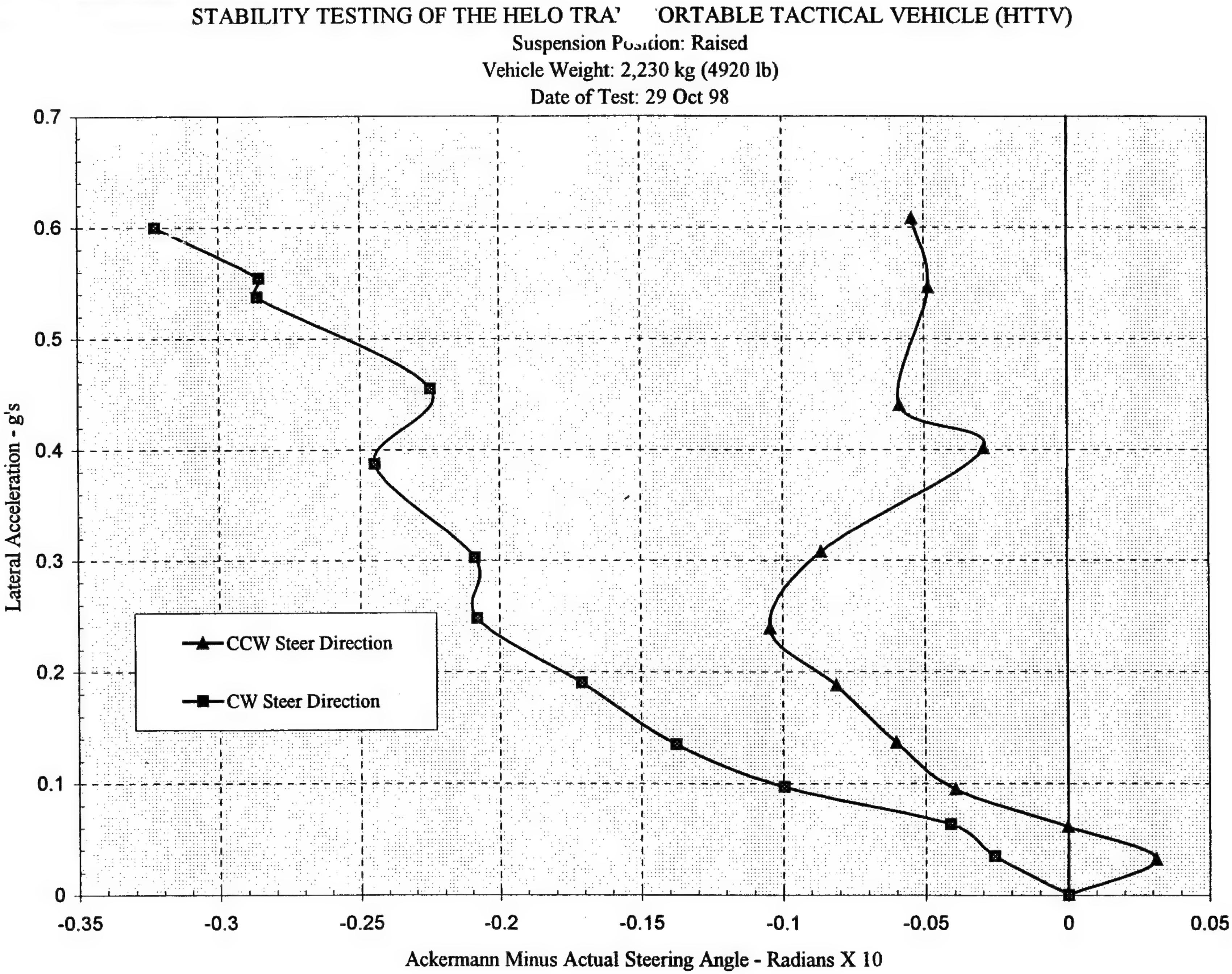


Figure 9. Handling Diagram for the HTTV, at VCW, with the vehicle suspension in the raised position, negotiating 30 m turn radius.

Appendix D

User Evaluations with the Helicopter Transportable Tactical Vehicle

CARDEROCK DIVISION
NAVAL SURFACE WARFARE CENTER

West Bethesda, Maryland 20817-5700

Marine Corps Vehicle and Expeditionary Systems Department

January 1998

User Comments

from

HTTV/JTEV Demonstrations

Prepared by

BOOZ•ALLEN & HAMILTON INC.

Distribution: Unlimited

Introduction

In October 1997, the Naval Surface Warfare Center (NSWC) displayed the Joint Tactical Electric Vehicle (JTEV) and two Helo Transportable Tactical Vehicles (HTTV) at the Special Operations Command (SOCOM) Headquarters, MacDill AFB. In November 1997, NSWC sent three HTTVs and the JTEV to Fort Campbell for assessment by a team of U.S. Army Special Operations personnel. In January 1997, NSWC provided the HTTV for use by Marines involved in an Urban Warrior LOE at Camp Lejeune. This report compiles comments from military personnel that operated the vehicles in the events described above. The personnel were solicited for their views regarding the desired features for vehicles they would use in performing their missions. For the Special Operations Forces the mission presented was a 10-day special reconnaissance mission in a desert environment. The Marine Corps comments pertained to operations in urban terrain and a three day reconnaissance mission. The comments are roughly grouped by categories found in Light Strike Vehicle Prime Item Specification.

These comments do not serve as design guidance unless specifically directed by the Government or called for in a contractual document.

Mobility

Speed

Any future vehicle needs to drive fast enough to keep up with other vehicles during administrative moves. Operators generally feel there is no need to exceed 75 mph.

Most movements are at sustained low speeds to minimize dust signatures.

During evasion, the crew may have to sustain top speed for several hours.

"Quickness" is desired to be able to break contact and outmaneuver a pursuing threat.

The general consensus was that acceleration was more important than top speed - drivers were impressed with the vehicle's acceleration.

Maneuverability

Several users commented that the turning radius of the vehicle was too large for a tactical environment with many obstacles. The vehicle was able to pass through an obstacle course only after reversing and forwarding several times.

Tires

If a trailer is part of the system, the tires for the trailer should be interchangeable with the vehicle. Trailers should not be considered as a primary means of meeting the load carrying goals. Most operators view trailers as undesirable since they limit mobility and obstacle negotiation.

One driver remarked that the HTTV was very difficult to back up with a trailer attached. This Marine had several years experience in backing up military vehicles with trailers.

Several drivers mentioned that the trailers should never be used in an unsecured area, as they impair the vehicles maneuverability too greatly.

6x4 ply tires are preferred over radials. Need puncture proof assurance.

Run Flats: some personnel swear by them, others have "torn them to shreds" in exercises and do not like them. The High Mobility Multi-Wheeled Vehicle (HMMWV) variant of run flat was bad (one comment) and is too hard to change. Some users will always take a full size spare in addition to patch kits.

Central Tire Inflation System(CTIS). Mixed comments. What is definitely needed is at least a 5 cfm air compressor which provides enough air to inflate one tire. The air hose should be long enough to reach all tires. A dual-use compressor is preferred to allow for tire inflation or use with auxiliary equipment (tools). A point made about CTIS (version unknown) is that it cannot seal the bead on a repaired flat tire. A system of providing compressed air from an engine cylinder was discussed as an option.

Rims. Concern voiced that Aluminum rims may break in rough desert operational areas.

All wheel drive adjusted by air locks with two or three axles.

Survivability

Any technology added to the vehicle should not hamper aircraft loading nor reduce payload. The survivability equipment's burden on the vehicle's power systems should be minimized. In addition, the survivability package should be modular to allow adaptation to changing threat conditions.

Must have low electronic emission signature.

The threat during a ground infiltration includes: 1) Border Police: including human and electric systems and dispersed mines, 2) Chance contact with civilians or paramilitary units, and 3) Security forces at the objective.

Mines are not considered a major threat in the interior of the operations area, but are likely along border areas.

Some operators feel the best protection is detection and avoidance. They would prefer a system that can give them warning of mines. It was the consensus of the team that pay-load weight should not be traded for armor. This was driven by the perception that armor protection at best, within gross weight constraints of the vehicle, would still be inadequate to offer meaningful anti-armor protection for the vehicle.

A desired feature was a system that could provide early warning of the presence of threat sensors.

Minimize IR pattern with integrated camouflage system, making use of nets and stealth technology.

The vehicle system should have mounts for Nuclear, Biological, and Chemical detection sensors. The vehicle and accompanying systems should be designed for easy chemical decontamination.

Muffled noise level of engine with no loss of horsepower.

Firepower

Tailorable crew-served weapons mount for machine gun or grenade launcher. Vehicle must be stable enough to employ . 50 cal machine-gun or automatic grenade launcher. Consider smoke dispensers fixed at each corner of vehicle.

An ammunition rack system should permit the storage of ammunition in a ready-to-use configuration to avoid ammunition box changes. Try to alleviate the need to change ammunition cans (Link into one long chain to feed gun) Require modular ammo racks.

The weapons station in the turret needs to be configured to facilitate easy ammo changes, quick locking in new orientations, and allow the operator to quickly duck inside of the vehicle. Also the weapon operator needs to be able to speak to navigator and driver- wireless intercom is preferred to prevent tangling as the turret is spun.

Mixed comments were received regarding a weapon mount for the vehicle commander. Most comments suggested a mount should be available.

There was worry that the M-2 .50 caliber could not be used effectively with the current mount.

Many drivers expressed satisfaction with the weapon mount. They said that it allowed the vehicle to "be its own escort", and that it was useful to have it interchangeable with the MK 19, 240 gulf, and the M-2 .50 caliber.

C4I & Reconnaissance, Surveillance and Target Acquisition Mission Packages

A wireless intercom that can be used while dismounted is desired.

Motorola Electronics products give lower output for UHF. No elaboration was given.

Vehicle should have a mount for the Global Positioning System (GPS) with an antenna integrated into the vehicle.

It is desired to have an integrated C4I system that is capable of giving bearing, distance, and location of targets in the Military Grid Reference System and geographic coordinates. This system should be capable of transmitting this information through a data port.

The vehicle's antennas and mounts should allow on the move communications using FM/UH/VHF. The antenna should be easy to bend or stow to allow for aircraft loading and for reducing the vehicle signature during missions.

Radio rack and power distribution panel that will mount and operate all radios used in the force and allow for mission flexible communications packages.

Optics should be able to be powered by the vehicle power system to reduce the need for batteries. Optics should be detachable for easy storage.

Optics should have adjustable daylight power settings of 25, 50, 75, and 100 w/ night amplified light source.

Thermal capabilities should be provided with adjustable power settings. Optics should be gyro-stabilized. Combine day-night sensor magnification.

The FLIR unit in one of the test models was unable to swivel. Operators stated that this makes the FLIR unit unusable to the driver when there is no passenger or A-driver.

External Interface Requirements

Towing

A vehicle should be self recoverable. The winch should be rated above the loaded vehicle weight . A winch is also used to enhance mobility. The placement of the winch mount should be carefully considered to allow clearance over obstacles and to protect the winch.

A fixed tow bar should be incorporated onto the vehicle. This bar should be able to collapse and fold into a bumper when stowed. Consider fold up tow bar that can double as a bush guard when secured across the front the of vehicle.

Other Vehicle Equipment (OVE) should include a snatch cable, a flexible tow rope that stretches then snaps, similar to bungie cord.)

Drivers were impressed by the towing ability and overall power of the HTTV. A mired 5-ton truck (M-923) was assisted out of a muddy area with the HTTV.

There was concern that the hitch would pull apart or otherwise damage a trailer if the vehicle were to pull the trailer at 45 mph or faster.

Both a front and rear winch would be favorable.

There is too much cable included in the winch, causing some operating problems. (Possible snapping of the cable in actual use).

Power

An inverter should be built into the vehicle. The measure as to whether the inverter is powerful enough is if it can run an electric drill or saw under a load.

Need to ensure slave receptacle is standard to the rest of the force and NATO.

It would be useful to have a solar panel that could recharge the vehicle's battery.

Need to have easy access to battery, 12 & 24 volt hookup points on battery. Ideal situation is to have a power distribution panel with 12 and 24 volt posts and push button breakers. The panel should be enclosed and protected but should be accessible for connecting accessories. Power distribution panel should also be able to recharge batteries.

HMMWV black box (computer) had problems in hot desert conditions, no elaboration available.

The operators desire a system that can automatically turn off the radios and other sensitive electronics when the vehicle ignition switch is turned on. Currently the radios have to be manually switched on/off upon vehicle start up.

A battery separate from the electrical system should be incorporated to allow for self jumping in the event of a dead battery.

The lighting system needs to be adaptable to tactical movement; no brake light when stopping, dash displays readable or interpretable at night, yet no signature carrying beyond the vehicle due to dash illumination.

Fuel System

Internal fuel tank must accommodate at least a 400 mile range. Auxiliary fuel tanks or carrying capability required to at least double that range with optimal onboard fuel capability to extend range up to 1500 miles desired. Additional built in fuel cells must be self-sealing. Additional fuel cells be configured to preclude the requirement for additional fuel pumps, the auxiliary cell replenishes internal fuel tank.

One concern was that diesel fuel would not be usable on a 21/30 day mission, and that there was no fuel injection available for diesel engines. A switch to gasoline was suggested, because it would be easier to locate gasoline reserves in a foreign country than diesel.

Transportability

Figure 1 shows the weight data recorded at Fort Campbell by B Company, 2/160th Aviation. Both vehicles drove onto four scales, one under each wheel. Notes reference loading on a CH-47E follow the diagram.

Vehicle Wheel Position	HTTV	JTEV
Front Left Wheel Weight	1,300 lbs	1,300 lbs
Front Right Wheel Weight	1,300 lbs	1,200 lbs
Rear Left Wheel Weight	1,100 lbs	1,200 lbs
Rear Right Wheel Weight	1,000 lbs	1,100 lbs
Total Vehicle Weight	**4,700 lbs**	**4,800 lbs**

Table 1. Vehicle Weight Distribution

One HTTV size vehicle, combat loaded, can easily fit on the CH-47E. Weight and dimensions become limiting factors when two combat loaded HTTV size vehicles are placed on the airframe. Trial vehicle loadings at Fort Campbell showed that the wheels of the last vehicle loaded will set on the ramp of the aircraft. The ramp has a 3,000 pound load limit, regardless of the position of the load. Since the ground vehicle is likely to be driven front-end first during tactical exfiltration, the heavier rear-end may preclude optional ramp positions due to excessive load.

To accommodate two combat loaded vehicles would necessitate a trade-off of external aircraft fuel reserves limiting on distances flown for infiltrations.

HMMWV tie-down clevis points are recommended. The following restraint criteria is the rule of thumb anticipated to apply to a RST-V being loaded on the CH-47E (TM 1-1520-252-10, p. 6-6-17).

Direction	Restraint Criteria
Forward	4.0 g's
Aft	2.0 g's
Down	4.0 g's
Up	2.0 g's
Lateral	1.5 g's

No lift points were provided on the vehicle that one group of operators used; recommended points for lifting were at the extreme front of the vehicle, and on top of the cab.

Flexibility and Expansion

Soft-Top Kit. Several operators commented on the effectiveness of the rain canvas in wet-weather conditions.

Mission Sustainability

Removable seats and general storage racks are required.

Possibly include a tie-down on hood for spare tire.

Minimum acceptable deep reconnaissance mission load requirement—4000 lbs.

Most military containers have rectangular edges. Recommend the cargo area of the RST-V be built with angles at 90 degrees to facilitate maximum use of available cargo space. Cargo space must include space for about 35 batteries of various sizes.

Need anti-armor/anti air weapons racks to provide for safe stowage of weapons. Currently PVC tubes are used which allows for vertical stowage of weapon with the warhead pointing down and the rocket engine up. Similarly, racks for individual rucksacks would be useful.

Many comments were made as to the lack of storage space in the vehicle. Operators improvised by piling personal equipment within the cab, but many operators felt that a variant with extended cargo area would be useful. Also, the operators felt that the vehicle would be very useful in evacuating casualties if it could carry more than one stretcher safely at a time. The operators designed an expedient brace to hold a stretcher securely.

Provide removable fuel and water racks to accommodate up to 40 gal of water in 5 gallon cans. Plan on at least one gallon of water per day for each man.

It was stated that an elevated air intake would be useful for fording.

Need cargo net for additional storage of equipment.

Need securable storage box for tools, communications equipment and other gear.

Additional cargo tie-down points on vehicle floor are needed. Consider side cargo rails that will have dual use as sand channels, vehicle climbing ladders and cargo attaching point. Provide miscellaneous interior and exterior shackle / tie-down points for equipment.

Current operators pretty consistently respond that they could not perform their missions in an all enclosed vehicle. If the vehicle is self-contained, this limits the amount and the configuration of equipment that can be carried. If sensors or other equipment requires cooling, operators suggested designing a self-contained system to cool the item.

Exhaust tailpipe-venting location. The exhaust could be vented into a rear wheel well area since this is unused space. This would allow for strapping cargo on the side of the vehicle without interfering with the exhaust outlet.

Many drivers report that the independent hydraulics system was useful in traversing cluttered terrain, and was used often.

Safety

Impact

The gunner must have protection in the event of vehicle rollover.

Emergency Egress

The personnel interviewed expressed concern with the difficulty to exit the HTTV. A tactical vehicle must allow for quick entry and the ability to quickly extract a driver that has become a casualty.

General

Driver needs to be sitting high enough to see over hood while negotiating obstacles. This is also a function of hood slope: though the slope on the HTTV hood impaired visibility, it did redirect air so it would not hit the operator in the face when operating without windshields.

One driver stated that the vehicle felt unstable when the hydraulics were fully elevated, and said that the gunner would have no protection in the event of a rollover.

The hydraulics were used by several drivers to increase their fields of vision, especially when climbing or descending a surface.

Vehicle must afford maximum observation to all crewmembers. May have hardtop or use canvas to protect the crew from the elements.

Human Factor Engineering Considerations.

Crew and Personnel

Any surface that could be walked on, especially the cargo area of the vehicle, should be non-slip.

Seats need to accommodate soldiers/marines wearing personal equipment: canteens, personal weapons, and ammunition.

Seats should be adjustable, both forward and back and up and down, to accommodate different size personnel.

Many operators comment that they like the overall seat design, but the seats need to be wider.

Many complaints were received on the harnesses - the operators felt that they took too long to put on, especially in a tactical situation.

Gas and brake pedals should be positioned relative to each other so a person wearing extreme cold weather boots can press one pedal at a time.

An adjustable steering wheel was mentioned as desired, especially for larger vehicle operators.

An area for resting the left foot is desired.

The heating system should be personalized instead of being an inefficient space heater in an open vehicle.

Drivers that operated a HTTV without a windshield or heater remarked that this limits the environments in which the vehicle can perform.

Controls, Instruments, Displays, Lights

Operators commented that the gear shift was hard to see in the dark, and further illumination was required.

Vehicle needs turn signals (these were not available on the vehicle the operator used).

It was suggested that the gear shift be moved onto the steering column for ease of access, as on a civilian POV.

The gauges were not properly illuminated, and were hard to see in the dark.

System Quality Factors

Maintainability

Skid plates on the undercarriage should be designed to allow for quick removal when maintenance is required.

Fluids check points must be easy to access.

Some operators felt that having only one pump in charge of the vehicle's hydraulics increased the chance of malfunction, which would render all hydraulics inoperable.

There is a need to shield the headlights from debris that is kicked up during normal operation. (Mesh or something similar was suggested)

A recommendation was made that all components of the lighting system be modular with that of a 5-ton (M-923 type).

It is desirable to have standardized fluids that are interchangeable between vehicles.

Vehicle should be configured to allow for extensive field maintenance.

Include in the vehicle maintenance kit: 1) A 48-inch jack, 2) A Pull-Pal self-extraction system, 3) One 30-foot, 50,000 lb. slingshot recovery strap, 4) Retractable slave cables (built into vehicle), and 5) Hard points for a jack emplacement forward of the rear wheels, and to the rear of the front wheels.

Design gunner's ring for maintainability. Include a pin locking system, or turret breaking system to quickly lock the ring in position, and release it from any firing position in a 360 degree circle.

Considerations for fuel input cap location. If it is on the top of the wheel well area, a horizontal surface (as on the HTTV), the crew will have to either not pack equipment on top of the area or, will have to move equipment every time they want to refuel. Also, if the cap is in a recession on a horizontal surface, dirt and/or water can collect in the recession, a nuisance. If the cap is on the side of the vehicle, a vertical surface, it is likely to be more accessible and less likely to accumulate contaminants.

Vehicle Components

Transmission

The operators were pleased with the HTTV transmission in terms of power for Forward and Reverse. Concern was ability to "find" gears and not slipping through gears; operators want to be able to get into gear easier than the HTTV shifter affords. Operators

like the push button release on the HMMWV gear shifter and the straight channel shifting on the HMMWV vice the maze pattern on the HTTV.

Skid plates

Skid plates on the bottom of the vehicle can protect vital areas, such as the transmission pans, fuel tank and radiator hoses, and are an asset in crossing obstacles.

In negotiating a deep, muddy puddle, the skid plate allowed the HTTV to "float" over the mud while the wheels "paddled" the vehicle across. The operator estimated the HMMWV would have gotten stuck. Note: for this particular driving test, the HTTV carried about a 1,700-pound load.

A drawback of skid plates is the added time for removing the panels to perform maintenance.

Heavy bumpers on the front and the rear are desired to protect the vehicle. A rubber bumper rail on sides of vehicle was also suggested.

Positive comments were made concerning the placement of the front tires. Drivers said that the extreme forward design of the wheels made it easier to negotiate obstacles.

Windshield. Windshields should be removable, pliable and non-glare.

<u>General Comments</u> (not germane to vehicle design)

Fuel Storage. One person described a 150-300 lb. capacity fuel bladder that dispenses fuel similar to a tube of toothpaste as a potential means of extending range while decreasing cargo space requirements as the mission progresses. The vehicle operator drives onto the bladder forcing fuel out a nozzle.

Operators should be able to open and close any cargo fasteners while wearing gloves.

Structural parts, especially roll bars, should be configured to use for hanging or tying down cargo.

Must consider ballast of liquid weights. Fuel cans can be moved around to balance weight, if liquid storage is included in vehicle design, a method must be available to ensure the vehicle can be balanced by the operator, such as, use of transfer pumps.

Idling does occur, but not for long periods: considerations are the effect on a diesel engine when idling (should idle at 1,200 rpm). An operator stated he will turn off the vehicle if a halt will last over 5 minutes-and that he is the one who knows how long he will be in one spot (unlike vehicles operating as part of a unit movement).

The effect of altitude on vehicle operation should be considered.

Cargo strap tie-down rails on the HTTV received highly favorable comments, but the rails should include an adapter to accept standard Air Force GDU straps.

The vehicle should be equally adapted to carrying cargo and for use as a light-weight, fast attack vehicle.

Should have some feature that allows for a push start.

Braking was not tested with instruments, but larger disk pads were recommended.

Steering was very responsive in the HTTV.

The suspension's adjustable ride height received favorable comments.

Urban comments. 1) Operators desire using vehicles in large buildings, e.g., warehouses, while conducting urban operations. The HTTV size was prohibitive for building entry in some of the buildings in the Lejeune MOUT site. 2) The HTTV was used for logistic support of urban operations at Lejeune. Operators felt the HTTV was inadequate in this capacity.

One Marine mentioned that braided hoses should not be used within the engine compartment, because they were too weak. No further elaboration was given.

Another comment referred to the difficulty of repairing the steel composite alloy.

Appendix E

V-22 Aircraft Fitcheck #1

V-22 OSPREY FIT CHECK

JOINT TACTICAL ELECTRIC VEHICLE (JTEV) AND NOTIONAL RECONNAISSANCE, SURVEILLANCE, TARGET ACQUISITION VEHICLE (RSTA-V)

15 JUNE 1996

V-22 Osprey Fit Check

Joint Tactical Electric Vehicle (JTEV) and Notional Reconnaissance, Surveillance, Target Acquisition Vehicle (RSTA-V)

Participants

In attendance at the fit check were:

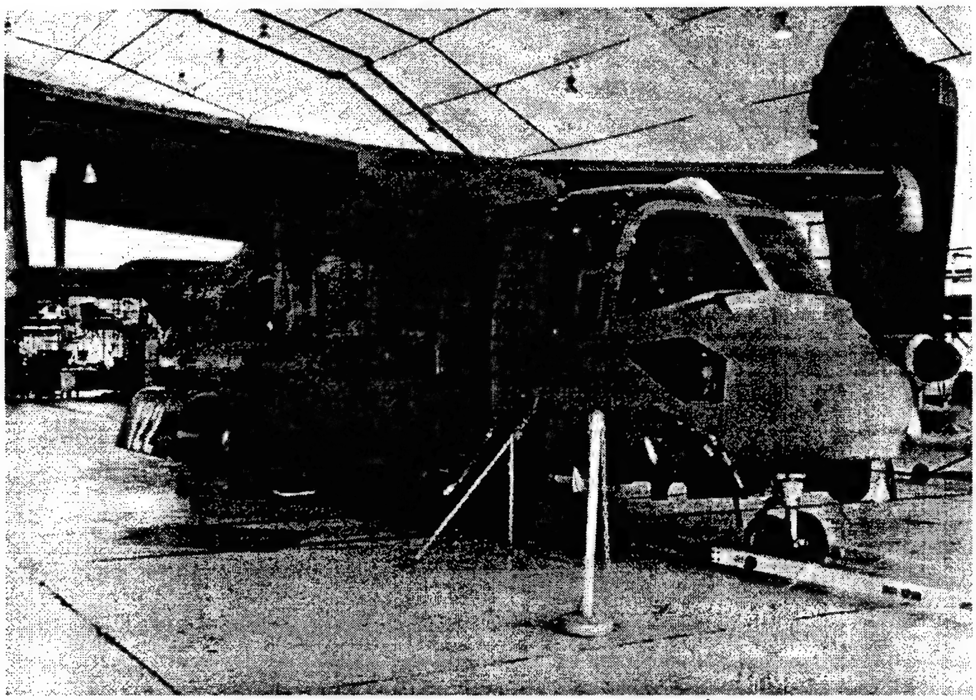
PARTICIPANT	ORGANIZATION	TELEPHONE
Ilker Bayraktar	AeroVironment	(818) 357-9983 x509
Richard Miller	DCMC Baltimore	(301) 342-7943 x162
GySgt D. Bramwell, USMC	HMX-1/V-22 MOTT	(703) 784-2923
SSgt Spidel, USMC	HMX-1/V-22 MOTT	(703) 784-2923/3303
Capt Jeff Wilson, USMC	MARCORSYSCOM	(703) 784-2006 x2715
Lee Siwinski	NAWCADWAR 4352	(215) 441-1975
Nick Runowich	NAWCADWAR 4352	(215) 441-2874
Carmen Cornetto	NSWC-Carderock	(301) 227-5002
Henry White	NSWC-Carderock	(301) 227-1274
Jeff Bradel	NSWC-Carderock	(301) 227-4222
Mike Gallagher	NSWC-Carderock	(301) 227-1852
Peter Congedo	NSWC-Carderock	(301) 227-5002
Maj Peter Petronzio, USMC	Recon Rqmnts, MCCDC	(703) 784-6209
GySgt Buttigieg, USMC	RM&S	(301) 342-4217
Sgt Boshuizen, USMC	RM&S	(301) 342-4217 x152
Douglas Steudler	Rod Millen Special Vehicles	(714) 847-2111
John LaPlante	Rod Millen Special Vehicles	(714) 847-2111
Shane Radford	Rod Millen Special Vehicles	(714) 847-2111
Larry Smith	V-22 ITT	(301) 342-7943 x138

Table 1., Participants

Introduction

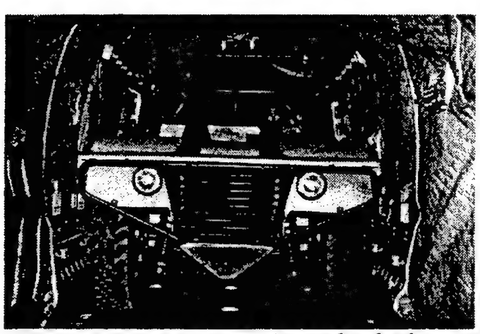
On 21 May 1996 representatives from the above listed organizations were present at NAS, Patuxent River to demonstrate the internal fit of the prototype Joint Tactical Electric Vehicle (JTEV) in a representative V-22 Osprey cargo bay and to collect data to determine the maximum reasonable dimensions for a future 8000 pound GVW Reconnaissance, Surveillance, Target Acquisition Vehicle (RSTA-V). This effort was sponsored by NSWC-Carderock Division, Marine Corps Programs Office under contract number N00167-96-C-0022 and hosted at NAS, Patuxent River by the V-22 Osprey Program Office. The event was recorded on video tape and further documented with extensive still photography. These media are available at NSWC-Carderock as required.

The non-flying V-22, Aircraft Number two (A/C-2) airframe was used for the demonstration and measurements, *Photograph nr. PSD 24260-06-96-9.* A/C-2 is a prototype, full scale demonstrator (FSD) version of the V-22. Several changes were made to A/C-2, in preparation for the interface tests to emulate the latest EMD configuration. It provided a fair representation of the production airframe less many of the fixtures and features to be incorporated in later versions.

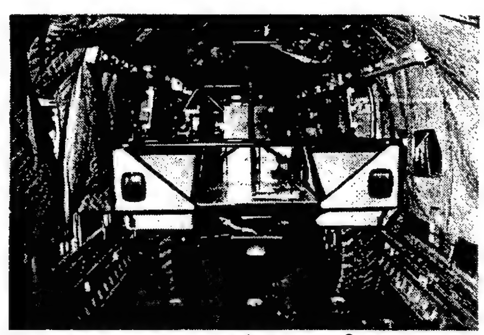


PSD 24260-06-96-9, V-22 Osprey FSD A/C-2

JTEV is a prototype hybrid electric vehicle built by AeroVironment, Inc., of Monrovia, California and Rod Millen Special Vehicles of Huntington Beach, California. It was designed and built to demonstrate the feasibility of electric hybrid technology in tactical off road application. It was originally sized for internal carriage in a CH-46, Sea Knight aircraft. The fit of the JTEV in the V-22 was successfully demonstrated facing both forward and aft at various ride heights, *Photogragh nrs. PSD 24263-06-96-16A and PSD 24264-06-96-24A.*

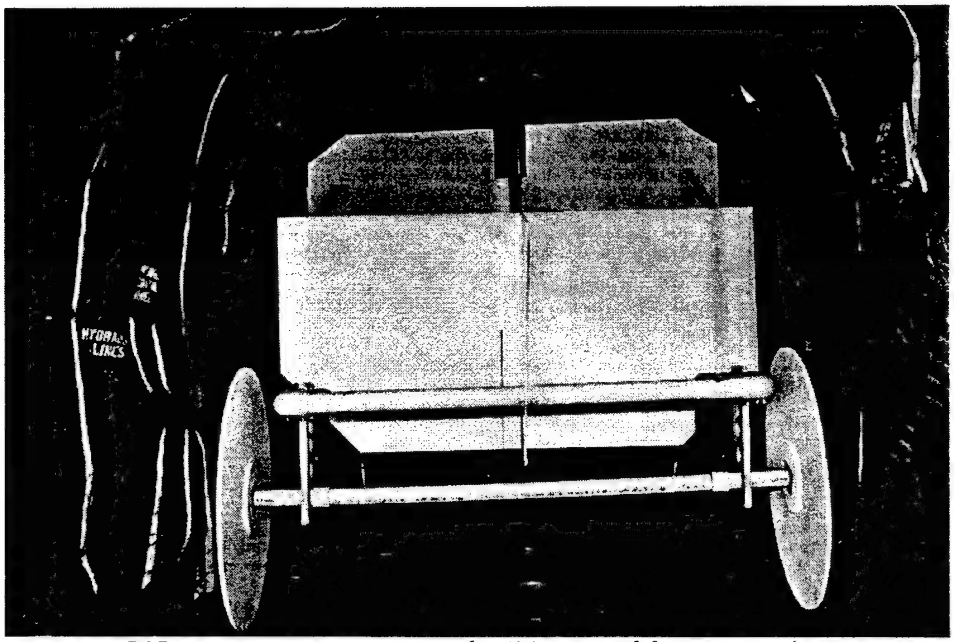


PSD 24263-06-96-16A, JTEV backed in



PSD 24264-06-24A, JTEV in forward

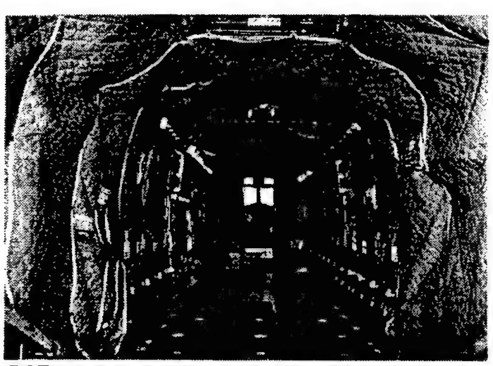
The RSTA-V notional model was constructed of foam board and PVC piping to be used as a tool to determine vehicle/airframe interference and measure clearances between the airframe and vehicle while entering, exiting and stowed. The foam board and PVC frame were cut and adjusted as necessary to determine the maximum dimensions possible, *Photograph nr. PSD 24259-06-96-19.*



PSD 24259-06-96-19, Notional RSTA-V model in V-22 A/C-2

V-22 Osprey Description

A/C-2 was a flying, full scale demonstrator. For the JTEV and notional RSTA-V fit checks it was modified to match the current engineering, manufacturing development (EMD) version of the aircraft. To simulate the EMD version, four troop seats were installed. A total of 25 troop seats will be fitted to the production aircraft arranged along each side facing inboard, 12 port and 13 starboard. Insulation and sound proofing were installed in the cargo area by means of aircraft thermal blankets. The thermal blankets are evident in *Photograph nr. PSD 24265-06-96-31A*.


PSD 24265-06-96-31A, V-22 FSD Cargo area

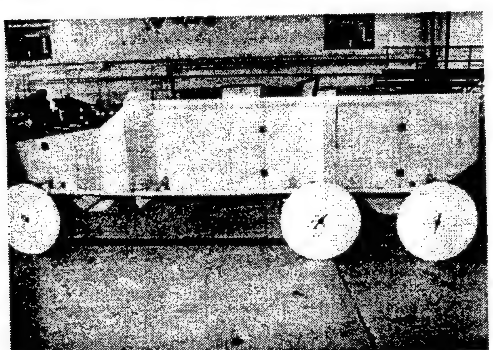

PSD 24265-06-96-28A, V-22 FSD ramp

A/C-2 was originally configured with a single loading ramp. The single piece ramp was removed and the bottom split ramp installed as in the future EMD aircraft. The actual short flipper ramps were not available, so wooden ramp extensions were constructed to simulate the flippers. The aircraft ramp angle was measured at 11.3 degrees and the wooden extensions had an angle of 14.4 degrees. The maximum ramp angle will be 18.5 degrees, as limited by the stroke of the ramp actuators. The cargo bay deck was parallel to the ground plane(measured at 0 degrees). The ramp configuration for the test can be seen in *Photograph nr. PSD 24265-06-96-28A*.

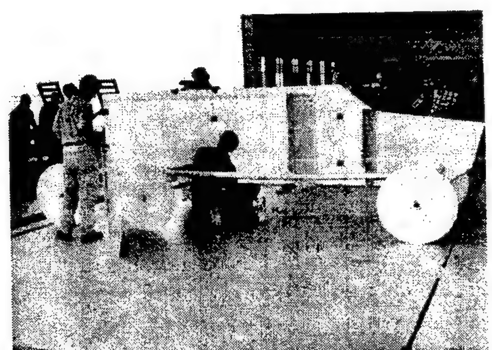
In preparation for the test general safety, security and housekeeping functions were accomplished. The nose of the aircraft was secured to the deck and jacks were installed at the aft jacking points to insure no upsetting moments were introduced into the airframe. Also, residual test instrumentation racks were removed and test wiring bundles were tied back out of the cargo area. *Addendum a., V-22 Cargo Area Dimensions and Specifications* is descriptive of the aircraft cargo bay geometry.

Notional RSTA-V Model Description

A full scale rolling model of a potential RSTA-V shape was constructed of PVC pipe, wood, and foam board, *Photograph nrs. PSD 24261-06-96-1 and PSD 24259-06-96-6*. The frame was made of two inch inside diameter PVC pipe and various 90 degree elbows and T fittings. The frame was rectangular, 57 x 178 inches long.



PSD 24261-06-96-1, Notional RSTA-V



PSD 24259-06-96-6, Model being assembled

The model was built in a three axle configuration, as shown in *Addendum c., Figure 1*. The front axle was positioned 6.58 inches aft of the forward-most frame crossmember. Axles two and three were set at 119 inches and 162 inches aft of the front axle respectively. These axle locations were chosen based on the JTEV's 119 inch wheel base with another aft axle positioned to allow approximately 12 inches between the rear tires.

The three axles were able to be positioned to yield 10, 12, 15 and 18 inches of ground clearance. The axles were also able to be adjusted to provide a 65 to 68 inch track width, adjustable in one inch increments. These settings were chosen as representative and reasonable heights for a high mobility, off road vehicle. The six wheels were made of one-half inch thick particle board, with reinforced centers. The radius of the wheels was 15.15 inches.

The body was made of 3/16 inch foam board. A single side profile and three different front profiles were cut out, one for the hood and windshield junction, another at the windshield and roof junction, and a third just aft of the second axle. *Addendum c., Figures 2 and 3* illustrate vehicle side and front body profiles. The front profile templates were designed with adjustable panels to change the maximum height of the vehicle from 58 to 74 inches in two inch increments. These dimensions were measured from the ground with the model set at 18 inches of ground clearance. The side profile was made in four pieces that were bolted together, end-to-end to form the backbone of the body. This backbone stood on the frame, centered between the left and right wheels. The backbone templates were slotted, along with their respective front profile pieces. These slots allowed the front and side profile templates to slip together and stay in place at 90 degree angles to one another thus forming a three dimensional envelope of the vehicle body. The body was located on the frame by slots to accommodate the frame crossmembers and rails. The body was hung below the frame to allow ground clearance dimensions to be measured directly to the predefined lower edge.

Test Procedure and Events

The JTEV was driven into and out of the V-22 forward and backward at low and high ride heights with and without the 50 caliber, M-2 machine gun mounted. Each configuration was tested several times. USMC aircrewmen monitored the clearance of each corner of the vehicle as it entered and excited the aircraft, *Photograph nr. PSD 24263-06-96-11A*. Clearances between the wheels and buffer boards, rollcage and ceiling, and gun and ceiling were checked and recorded by taking photographs of tape measures held in place to illustrate clearances.

PSD 24263-06-96-11A, JTEV Backing in

PSD 24259-06-96-33, RSTA-V model exiting

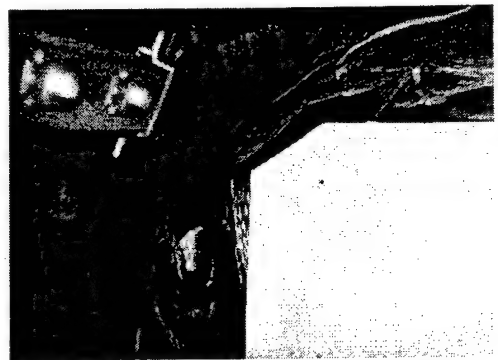
Next the RSTA-V model was assembled and rolled in and out of the V-22, *Photograph nr. PSD-24259-06-96-33*. This was done forward and backward. The adjustable panels on the front profile templates were mounted 64 inches from the ground. At this height it was known that there would be interference between the model and the inside of the aircraft. Triangular pieces of the outer corners of these adjustable panels were trimmed to eliminate interference with the interior of the aircraft. This was done until the model rolled in and out of the aircraft with no interference. The final dimensions of the triangles that were removed were approximately 4 by 6 inches, *Photograph nrs. PSD 24259-06-96-14 and -15*. The 4 and 6 inch dimensions were oriented vertically and horizontally respectively. This exercise was utilized to determine the maximum vehicle envelope.

V-22 CARGO AREA

DIMENSIONS AND SPECIFICATIONS

Addendum a.

PSD 24259-06-96-14, Removing interference



PSD 24259-06-96-15, Optimized model

Once this was done the model was positioned in the cargo bay of the V-22 to check for access to tie-downs, clearance of seats, storage of life-raft, and location of vehicle center of gravity with respect to the aircraft's cargo center of gravity envelope to provide for stable flight.

Results

The sequences, attached as *Addendum b., CAD Drawings of a Notional RSTA-V / V-22 Interface*, illustrate the approximate breakover clearance and the interference associated with the RSTA-V model being fit into the V-22 with the ramp angle set at the maximum 18.5 degree position. Sequences 1-4 show the model backing into the V-22 at all four ride heights with no suspension travel, Sequences 5-8 also show the model backing into the aircraft but this time with approximate suspension travel, Sequences 9-12 show the model rolling forward into the V-22 with no wheel travel at all four ride heights, and Sequences 13-16 show the model rolling forward into the aircraft with approximate wheel travel at all four ride heights. *Tables 2 through 5* below summarize the minimum clearance and maximum interference for each configuration at the various ride heights.

SEQ. NR.	GROUND CLEARANCE	BREAKOVER CLEARANCE	OVERHEAD CLEARANCE
1.	18	8.8	-9.0
2.	15	6.5	-6.1
3.	12	2.8	-3.2
4.	10	0.8	-1.9

Table 2., Back in minimum clearances with no wheel travel (measurements in inches/negative equals interference)

SEQ. NR.	GROUND CLEARANCE	BREAKOVER CLEARANCE	OVERHEAD CLEARANCE
5.	18	3.0	0.0
6.	15	1.3	1.9
7.	12	0.3	1.6
8.	10	-1.4	1.1

Table 3., Back in minimum clearances with wheel travel (measurements in inches/negative equals interference)

SEQ. NR.	GROUND CLEARANCE	BREAKOVER CLEARANCE	OVERHEAD CLEARANCE
9.	18	8.8	1.2
10.	15	5.7	4.2
11.	12	2.7	7.2
12.	10	0.7	9.2

Table 4., Front in minimum clearances with no wheel travel (measurements in inches/negative equals interference

SEQ. NR.	GROUND CLEARANCE	BREAKOVER CLEARANCE	OVERHEAD CLEARANCE
13.	18	3.1	1.2
14.	15	1.5	4.2
15.	12	0.9	7.2
16.	10	-1.4	9.2

Table 5., Front in minimum clearances with wheel travel (measurements in inches/negative equals interference)

The sequences show there will be interference between the ramp and the underside of the vehicle when the ride height is set at 10 inches and the vehicle is backed into the aircraft, and when the ride height is set at 10 and 12 inches and the vehicle is driven forward into the aircraft.

The sequences also show approximate range of breakover clearances between the ramp and the underside of the vehicle. When the vehicle was backed into the aircraft, the range of breakover clearances were 3.0 to 6.7 inches at the 18 inch ride height, 1.3 to 6.1 inches at the 15 inch ride height, and 5.4 to 0.3 inches at the 12 inch ride height. When the vehicle was rolled forward into the aircraft, the range of breakover clearances were 9.9 to 3.1 inches at the 18 inch ride height and 7.2 to 1.5 inches at the 15 inch ride height.

Issues

In order to determine the vehicle stowage requirements and interface with the airframe the concept of operation/mission scenario need further delineation. Questions relating to the concept of operation/mission scenario include crew access requirements for both vehicle personnel and aircrew and sensor suite/weapon deployment doctrine. Access to the vehicle tiedown points aft during a tactical debarkation is a consideration as forward to aft movement is restricted with the vehicle in place. Tiedown criteria for a 8000 pound GVW vehicle in a V-22 need to be established. The number of tiedowns, their location and rating of the ties were estimated for the test and demonstration, but not formalized. As previously noted, the FSD aircraft ramp used in this test was constructed to simulate the ramp dimensions and a representative deployed ramp angle of the V-22. It was reported by the V-22 Program Office the future V-22 EMD aircraft ramp will have a 5000 pound weight limit. The configuration of this ramp, wheel base and weight distribution of a loaded 8000 pound GVW RSTA-V is a significant design issue not yet addressed. A more robust V-22 ramp could be considered so as not to unduly constrain the design and subsequent loading of a RSTA-V.

Safety of flight issues include matching of the RSTA-V center of gravity with the available aircraft cargo center of gravity envelope, crew seating requirements, electromagnetic interference for a hybrid electric vehicle, and foreign object damage (FOD). In a vehicle optimized to take advantage of the entire length available in the cargo bay, vehicle location inside will be severely restricted. Thus restricted to a specific location and tiedown arrangement, the vehicle center of gravity will need to be carefully considered to fall within the prescribed aircraft cargo center of gravity envelope.

Crew seating will be impacted by the vehicle. The proposed seating configuration is 12 seats port and 13 seats starboard facing inboard. The seat pans are rotated upward against their respective seat backs for storage. The seats are protected in their stored position by buffer boards, see *Addendum a., page 7.* A set of six adjacent seats are protected by one buffer board. Any vehicle of adequate length to be mission effective will interfere with all four buffer boards making all of the crew seats undeployable.

The impact of electromagnetic interference (EMI) between the aircraft and the vehicle are undetermined. If the RSTA-V is a hybrid electric vehicle operating at high voltage and current loads, this may pose a significant safety of flight issue. A/C-2 was not powered at the time of the JTEV demonstration and no data were collected.

Housekeeping restrictions with regard to FOD introduced into the cargo bay by embarking a vehicle in a landing zone after a mission need to be defined. Flight controls and other aircraft systems may be susceptible to debris introduced by the RSTA-V.

The demonstration, test, and analysis detailed the aircraft and RSTA-V interfaces. The RSTA-V profile will be dependent on the interaction of the vehicle and aircraft as a function of the break angle of the ramp. It is most probable that in a tactical situation the vehicle will be backed into the cargo bay. When recovering the vehicle from the field it would be driven in forward. This enables the most expeditious and safe exit from and entrance to the aircraft. Driving in forward, as expected, presented no interference/clearance problem. In backing the vehicle into the cargo bay, the height of the roof line will be restricted by the clearance at the top of the aircraft's ceiling, see *Addendum c., Figure 4.* Likewise, the ground clearance of the vehicle will be defined by the break over clearance. *Addendum c., Figure 5* shows an acceptable minimum ground clearance of three inches for a three axle vehicle with axles two and three set at 119 and 162 inches aft of axle one. This is a reasonable ground clearance for a vehicle optimized to fill the length of the aircraft cargo bay.

Summary

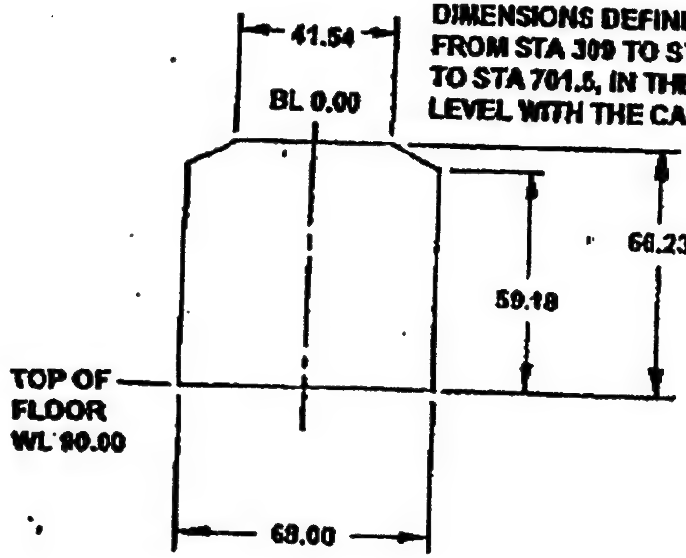
V-22 interface tests were conducted using the Joint Tactical Electric Vehicle and a notional Reconnaissance, Surveillance and Target Acquisition Vehicle mockup. The JTEV fit into the cargo area with approximately 1.5 inches on each side. As noted, several questions were brought to light during the interface tests. It is recommended that the V-22 Program Office and PM-Ground Weapons, NSWC-Carderock Division be contacted when addressing these issues. Copies of this report are available from NSWC-Carderock.

V-22 CARGO AREA

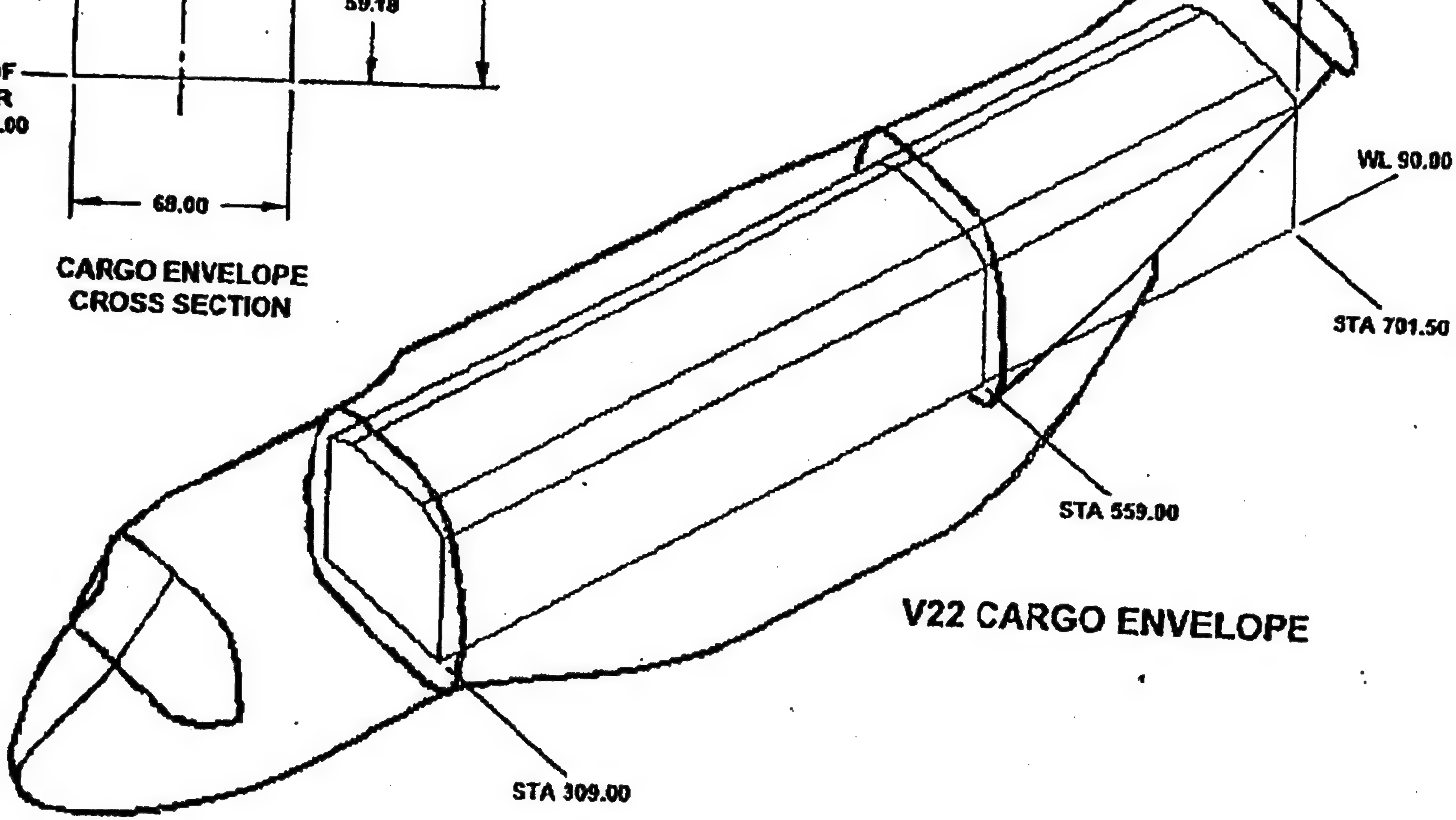
DIMENSIONS AND SPECIFICATIONS

Addendum a.

DIMENSIONS DEFINE THE SHAPE THAT MUST BE CLEAR FROM STA 309 TO STA 559, IN THE CABIN, AND FROM STA 559 TO STA 701.5, IN THE AFT FUSELAGE, WITH THE *RAMP* FLOOR LEVEL WITH THE CABIN FLOOR.



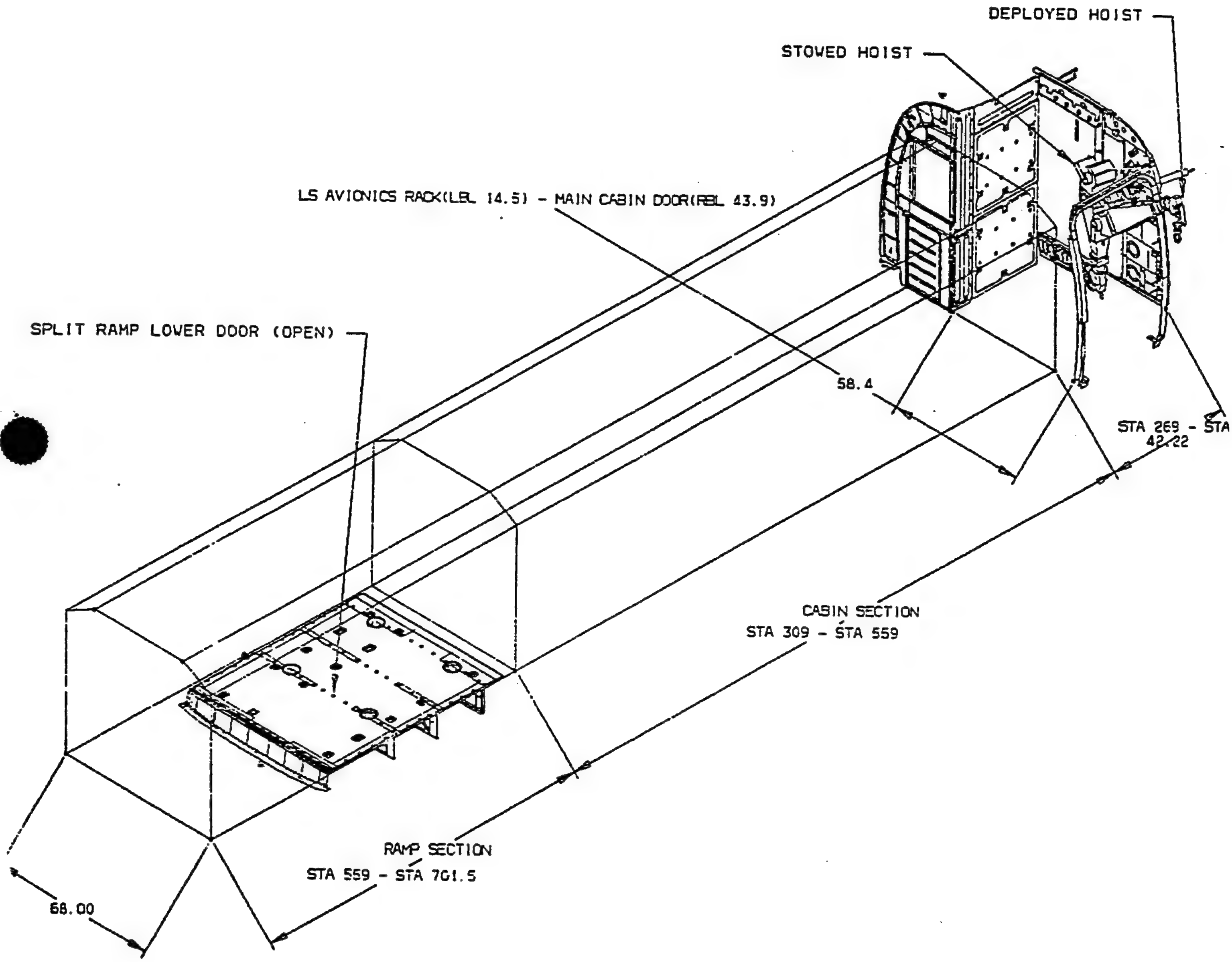
CARGO ENVELOPE CROSS SECTION



V22 CARGO ENVELOPE

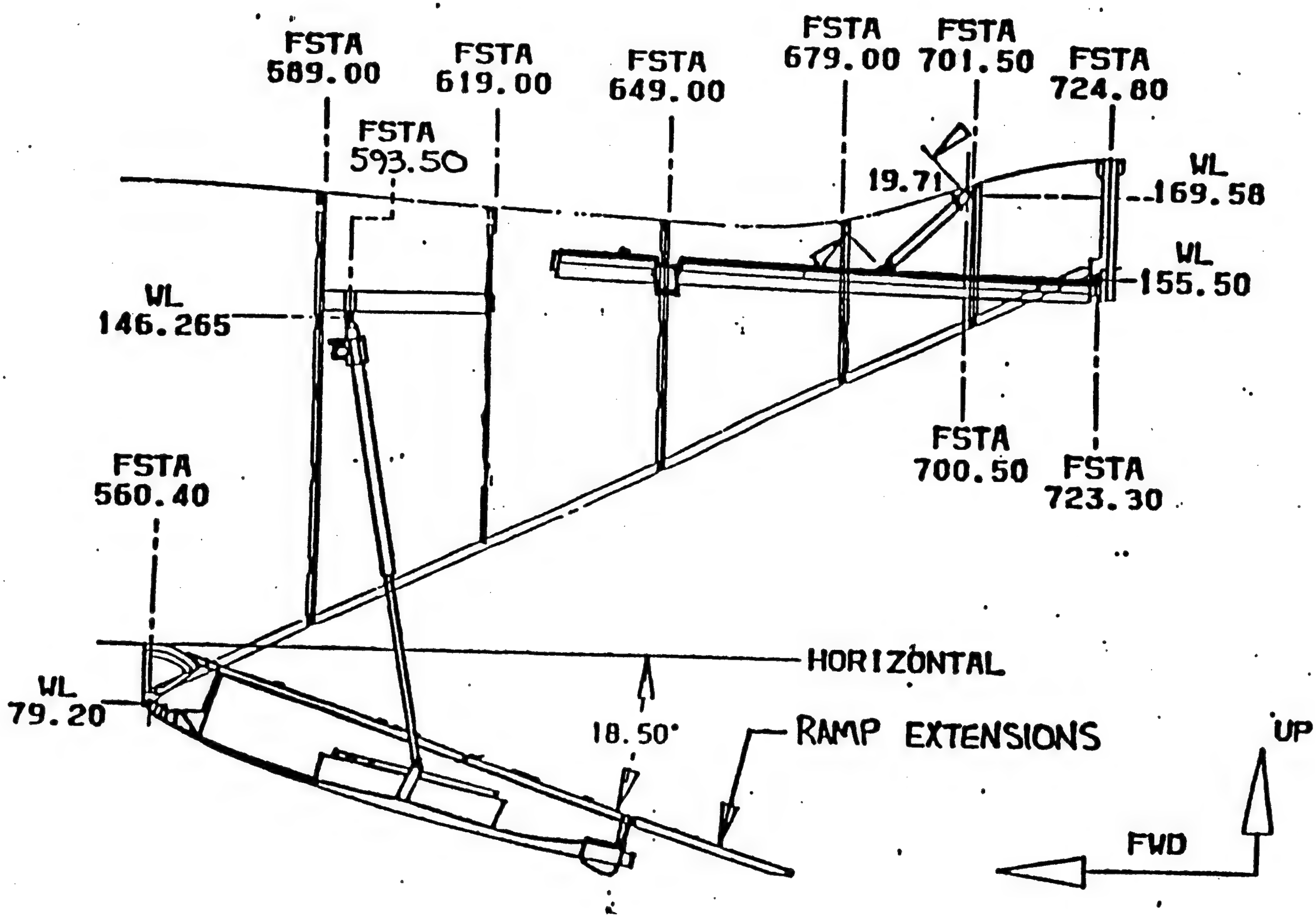
Y
H

EMD V-22 CARGO COMPARTMENT
WIDTH DIMENSION
STA 269 THRU STA 701.5
(FORWARD AREA REDUCTION OF 7.25 IN. W/HOIST)



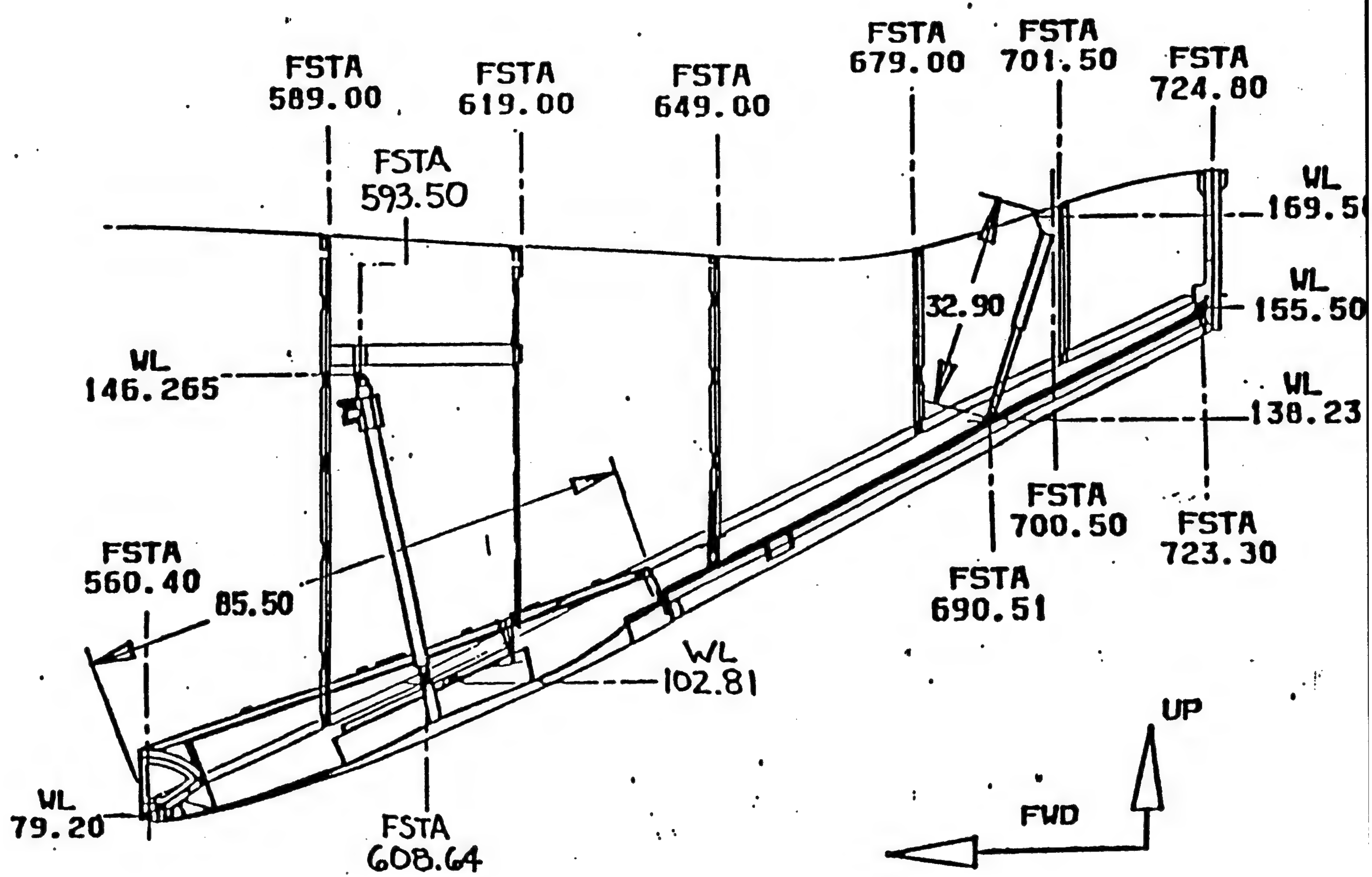
PROFILE RAMP/ DOOR OPEN

SPLIT RAMP
9 SEPTEMBER 199



PROFILE RAMP/DOOR CLOSED

SPLIT RAMP
9 SEPTEMBER 199



Ramp
Configuration Overview

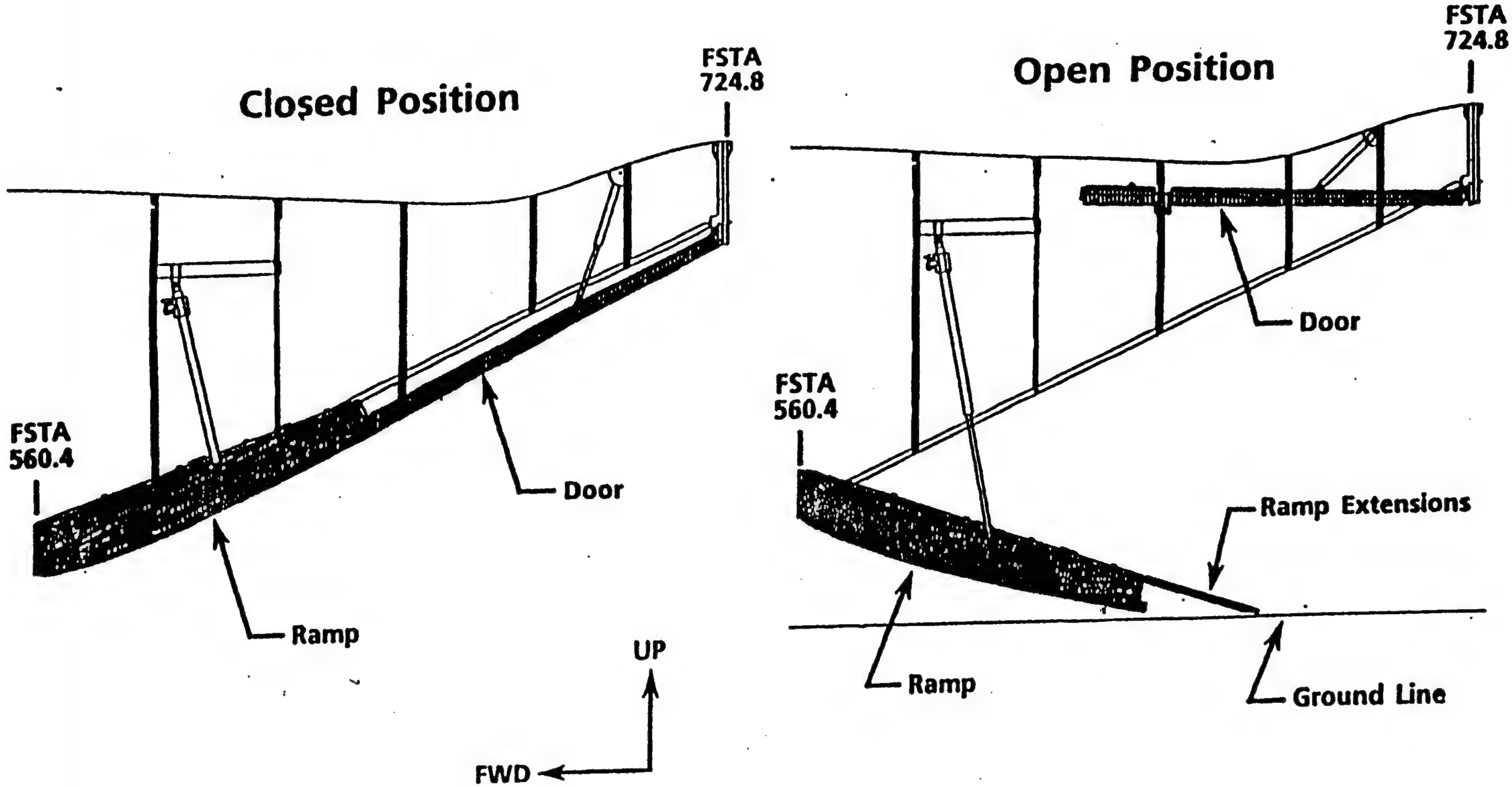
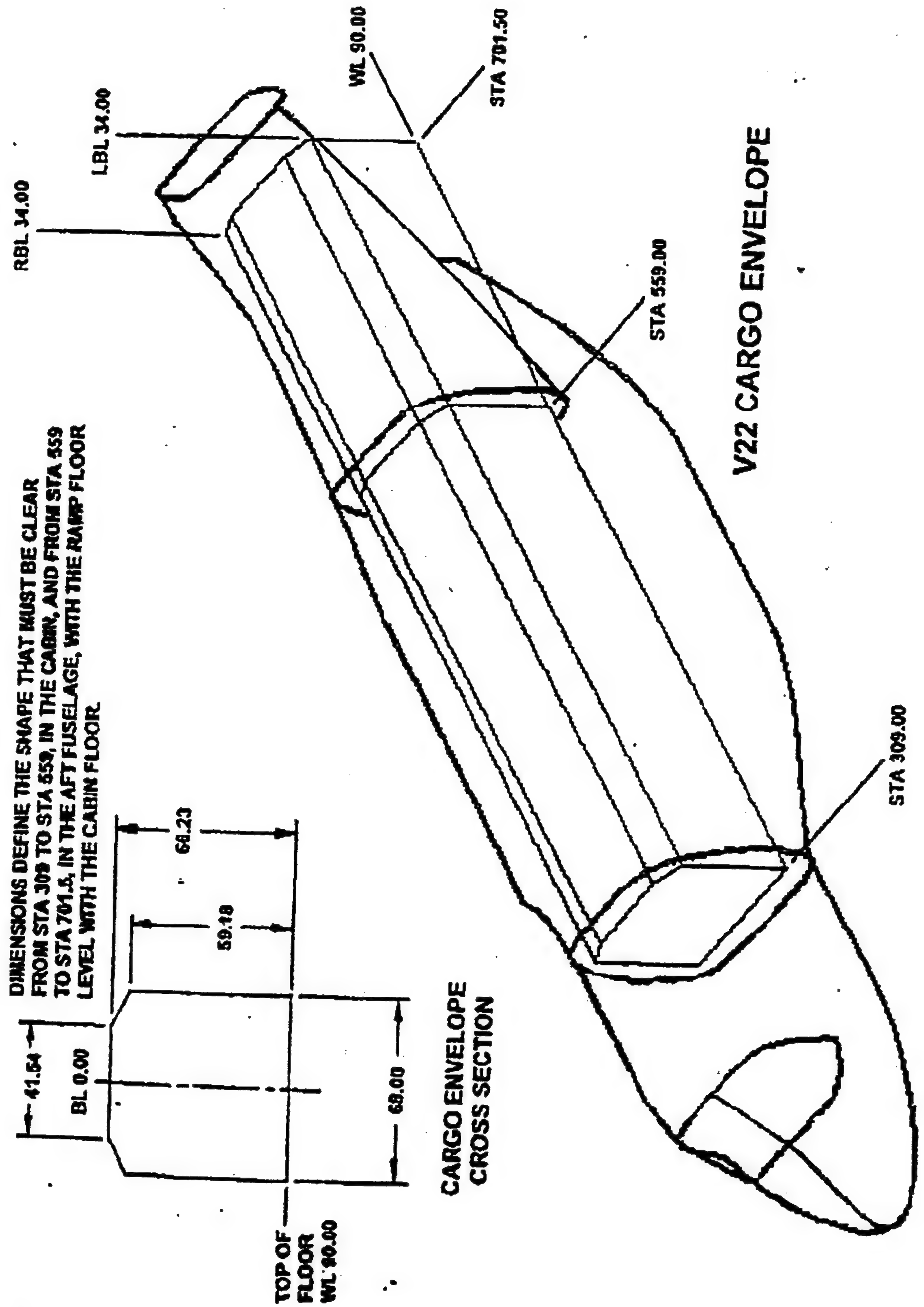


Figure 1.15-5

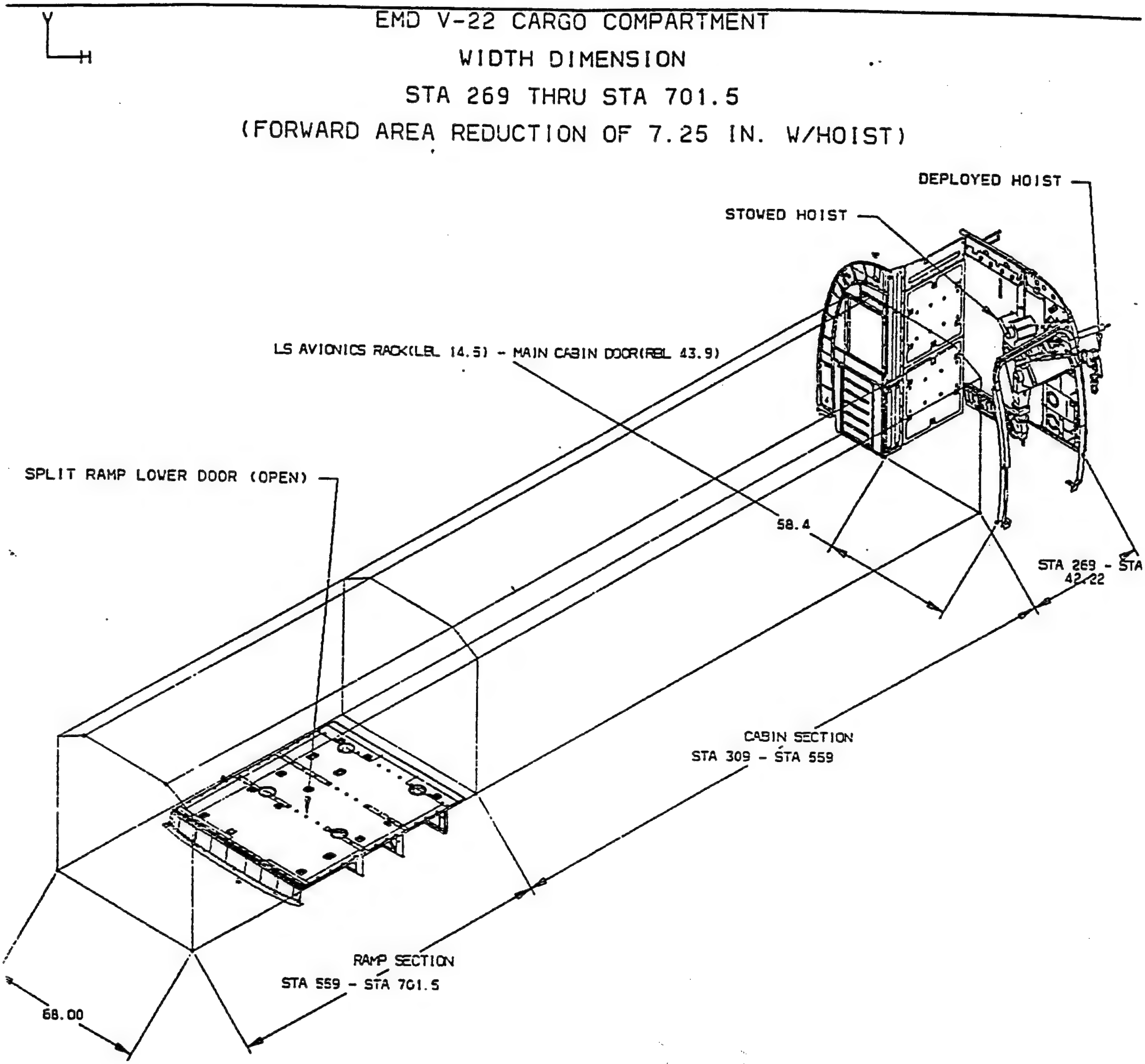

V22 CARGO ENVELOPE
WL 90.00
STA 701.50
LBL 34.00
RBL 34.00
STA 559.00
STA 309.00
DIMENSIONS DEFINE THE SHAPE THAT MUST BE CLEAR FROM STA 309 TO STA 559, IN THE CABIN, AND FROM STA 559 TO STA 701.5, IN THE AFT FUSELAGE, WITH THE RAMP FLOOR LEVEL WITH THE CABIN FLOOR
66.23
59.18
41.54
BL 0.00
68.00
TOP OF FLOOR WL 90.00
CARGO ENVELOPE CROSS SECTION

EMD V-22 CARGO COMPARTMENT

WIDTH DIMENSION

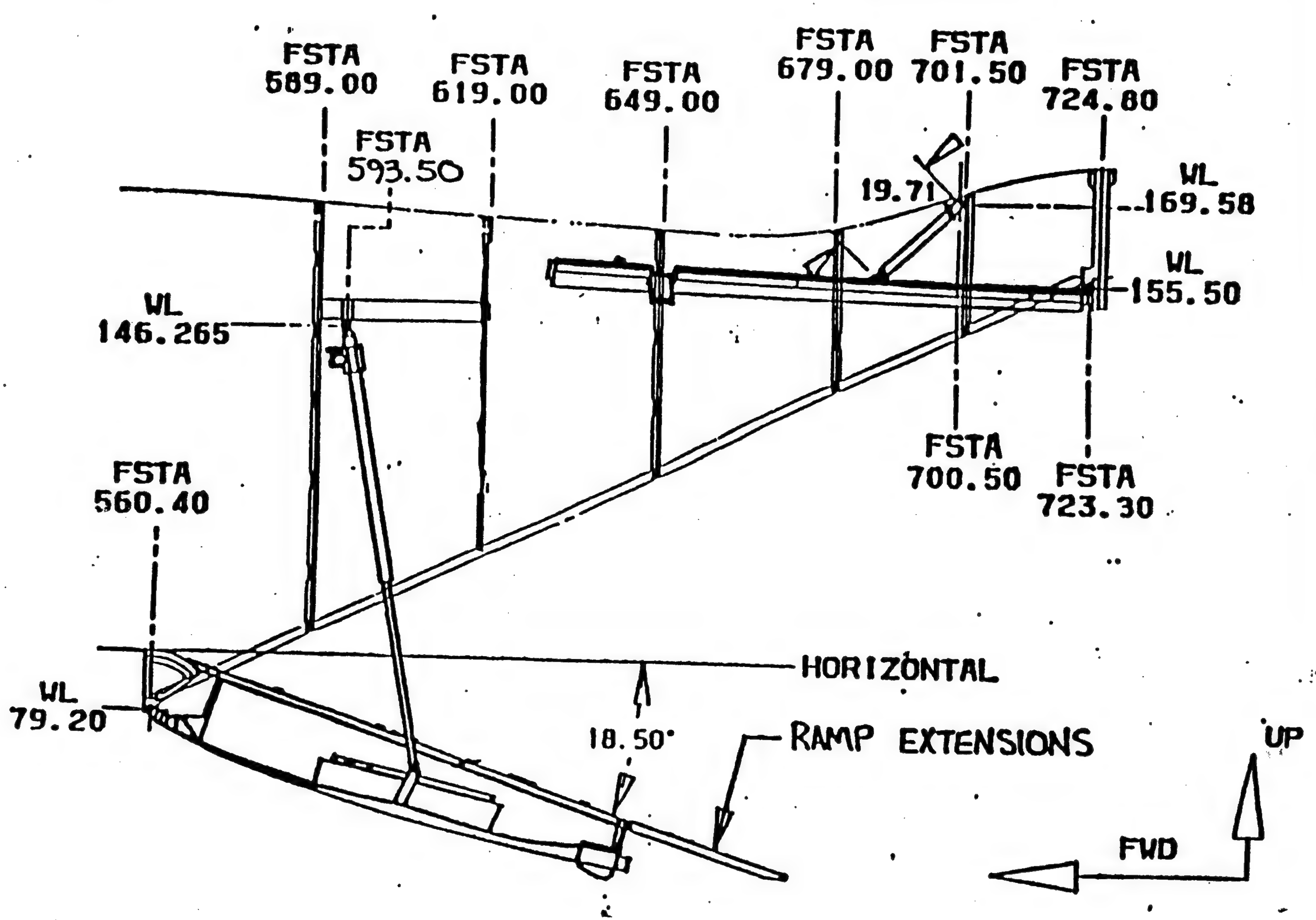
STA 269 THRU STA 701.5

(FORWARD AREA REDUCTION OF 7.25 IN. W/HOIST)



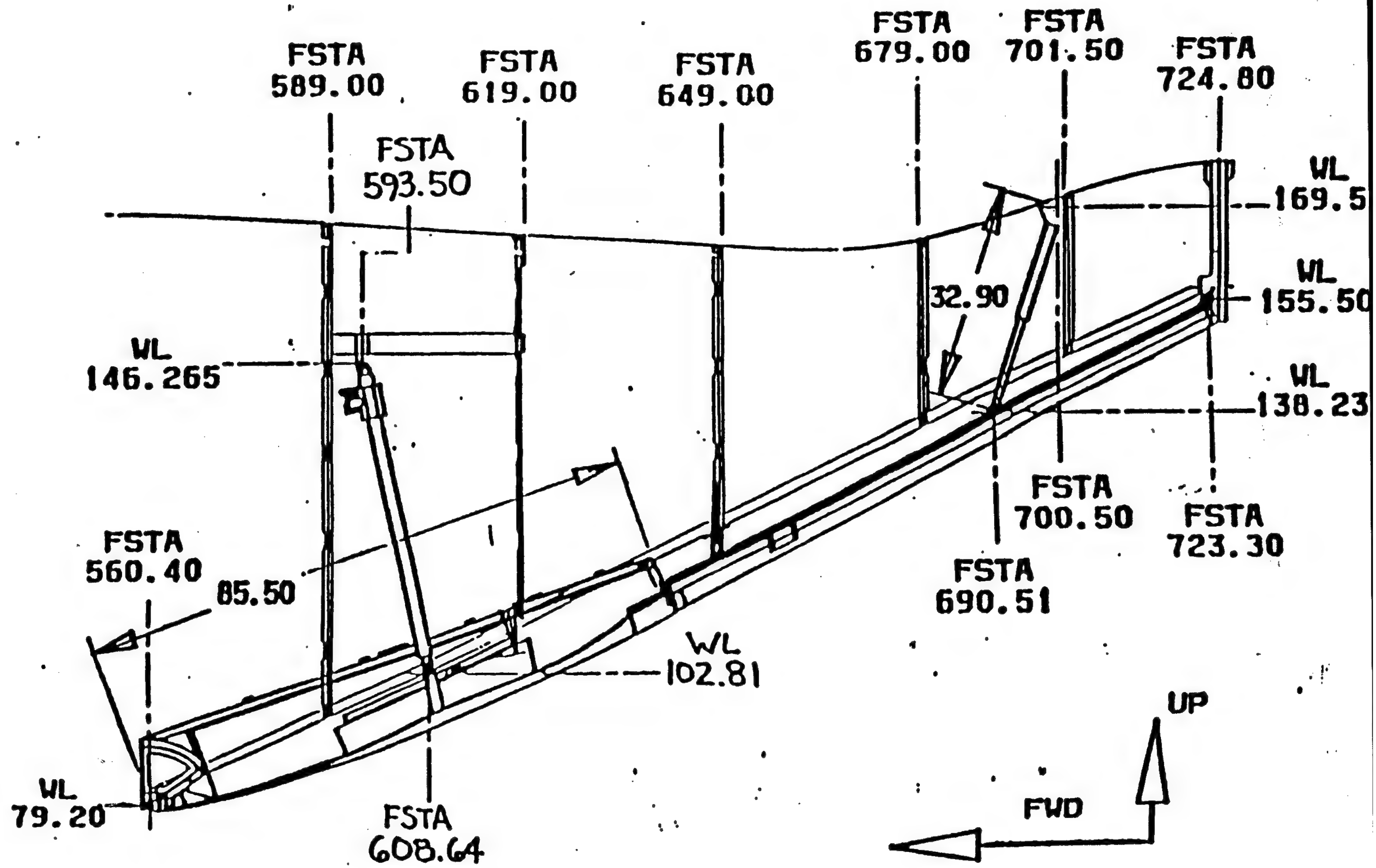
PROFILE .RAMP/ DOOR OPEN

SPLIT RAMP
9 SEPTEMBER 199



PROFIL RAMP/DOOR
CLOSED

SPLIT RAMP
9 SEPTEMBER 199



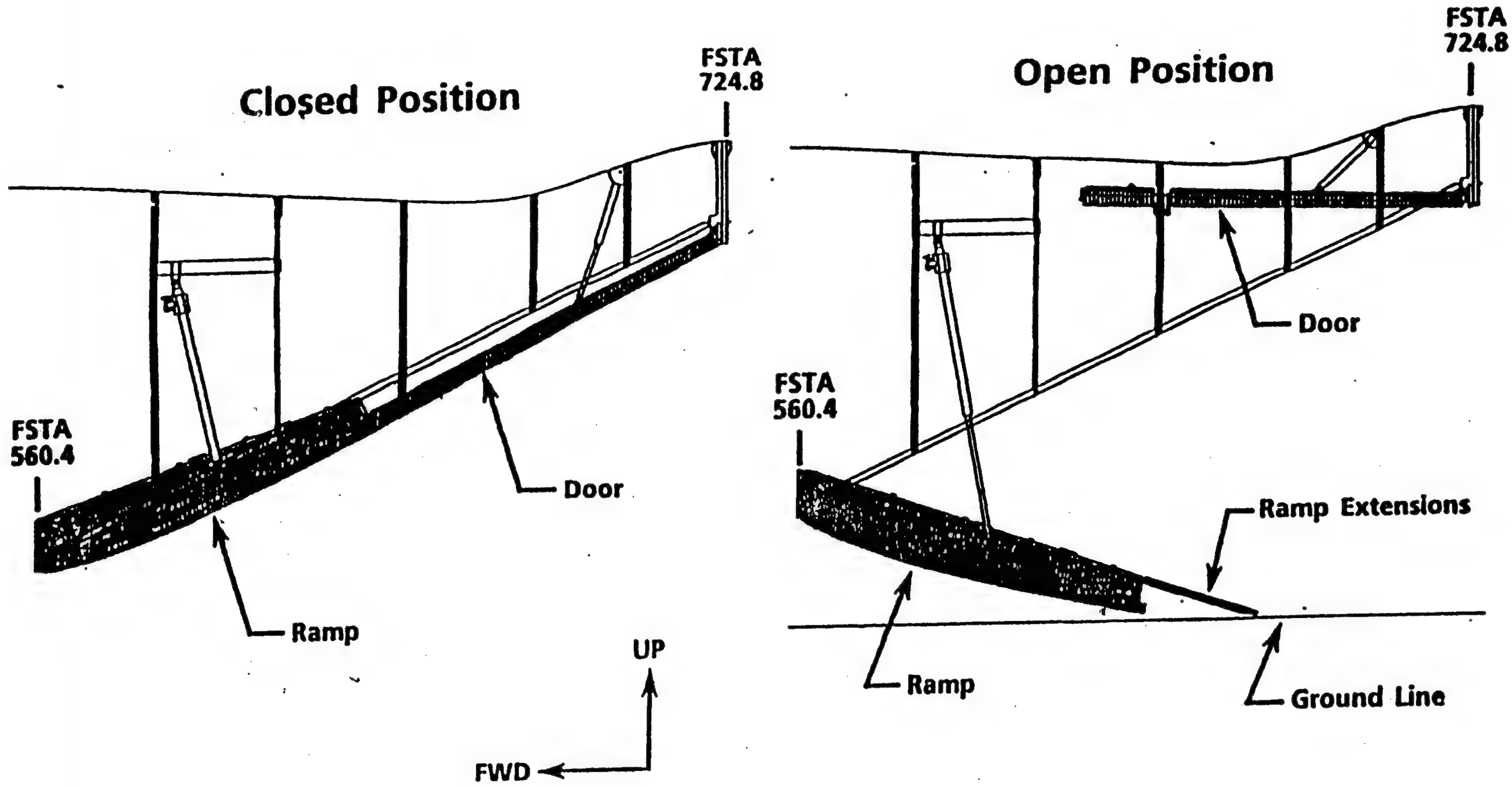
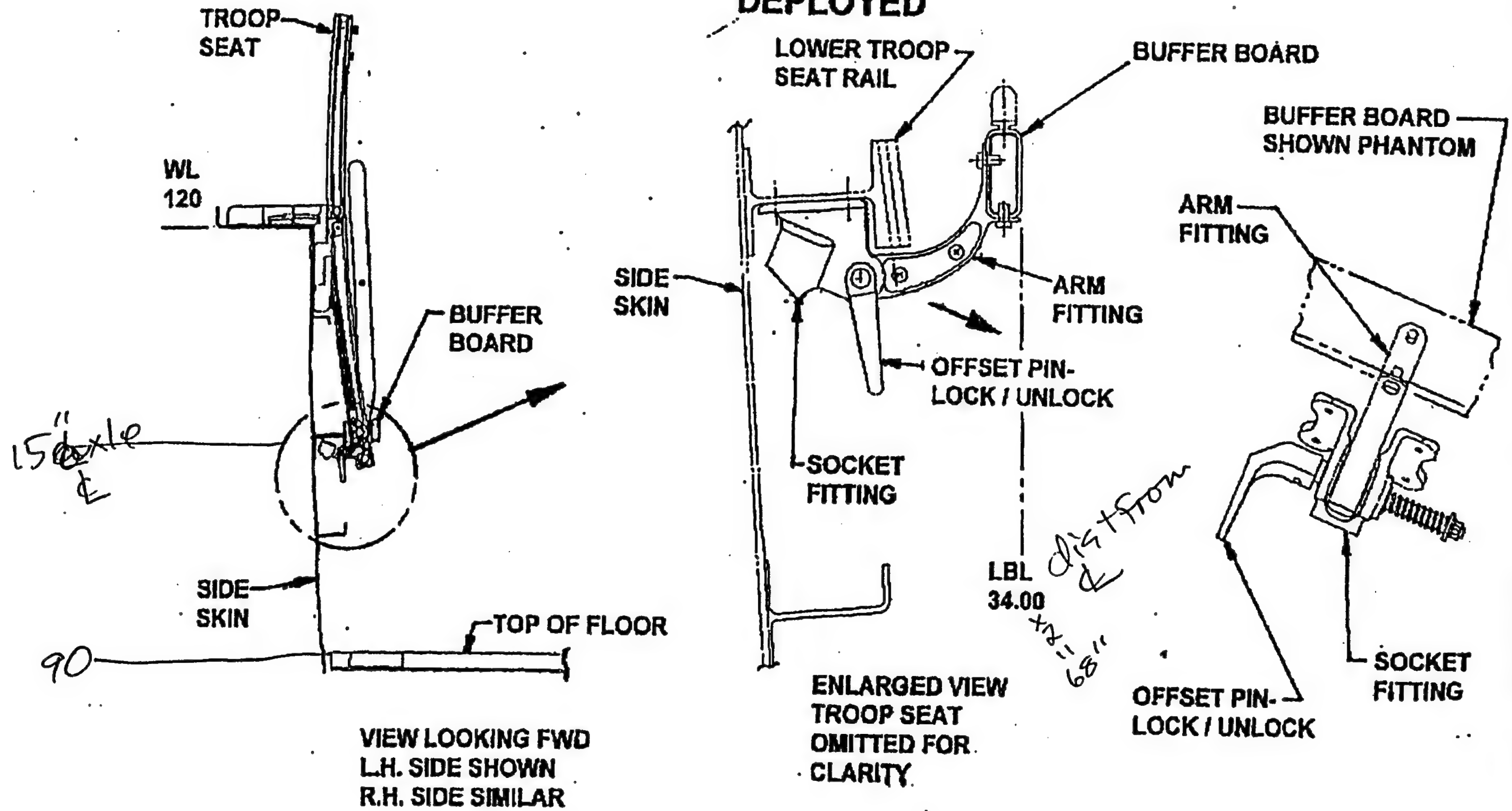

Closed Position
Open Position
FSTA 724.8
FSTA 560.4
Door
Ramp
FSTA 724.8
FSTA 560.4
Door
Ramp Extensions
Ramp
Ground Line
UP
FWD

Figure 1.15-5

PAYLOADS / EQUIPMENT IPT
INTERNAL CARGO HANDLING
CHANGES SINCE PDR

SYSTEMS CDR
12 OCTOBER '94

CDR BUFFER BOARDS
DEPLOYED



13400
Ser 53033F/5.13281

MEMORANDUM

From: AIR-53033F
To: AIR-5115X1

Subj: MV-22 CARGO BAY DIMENSIONS AND LIMITATIONS

Ref: (a) MCRDAC ltr 3000, C21A undated
(b) SD-572-1, MV-22 Detail specification

Encl: (1) MV-22 Cargo Bay Envelope diagrams

1. As per referance (a) request, specific MV-22 Cargo Bay demensional and cargo floor level data are submitted by the following paragraphs.

2. Cargo bay dimensions are outlined in enclosure (1). The fore and aft hatch doors ar. located on B.L. 15, LH/RH sides. The vertical clearance of (6) six inches min. should be maintained for loud/unload operation on the ramp in the down position and inside the cabin. Side clearance of (6) six inches (min) is required. In addition, a passageway for crewman access to the aft station fire extinguisher, tie-down fittings, etc. is necessary.

3. The floor load level is 300 lbs/ft^2 anywhere on the cabin and ramp. Floor loading for wheeled vehicles is 50 lbs/in^2. Since the floor is uniformily constructed of honeycomb, the treadway limits are unlimited.

4. It is recommended that Navair be advised of available vehicular tie-down hard points in order to evaluate the tie-down pattern to the cargo crash load criteria.

5. POC for the above is Mr. Hank George, AIR-53033F, 692-3642/3.

Hank George
7-26-91

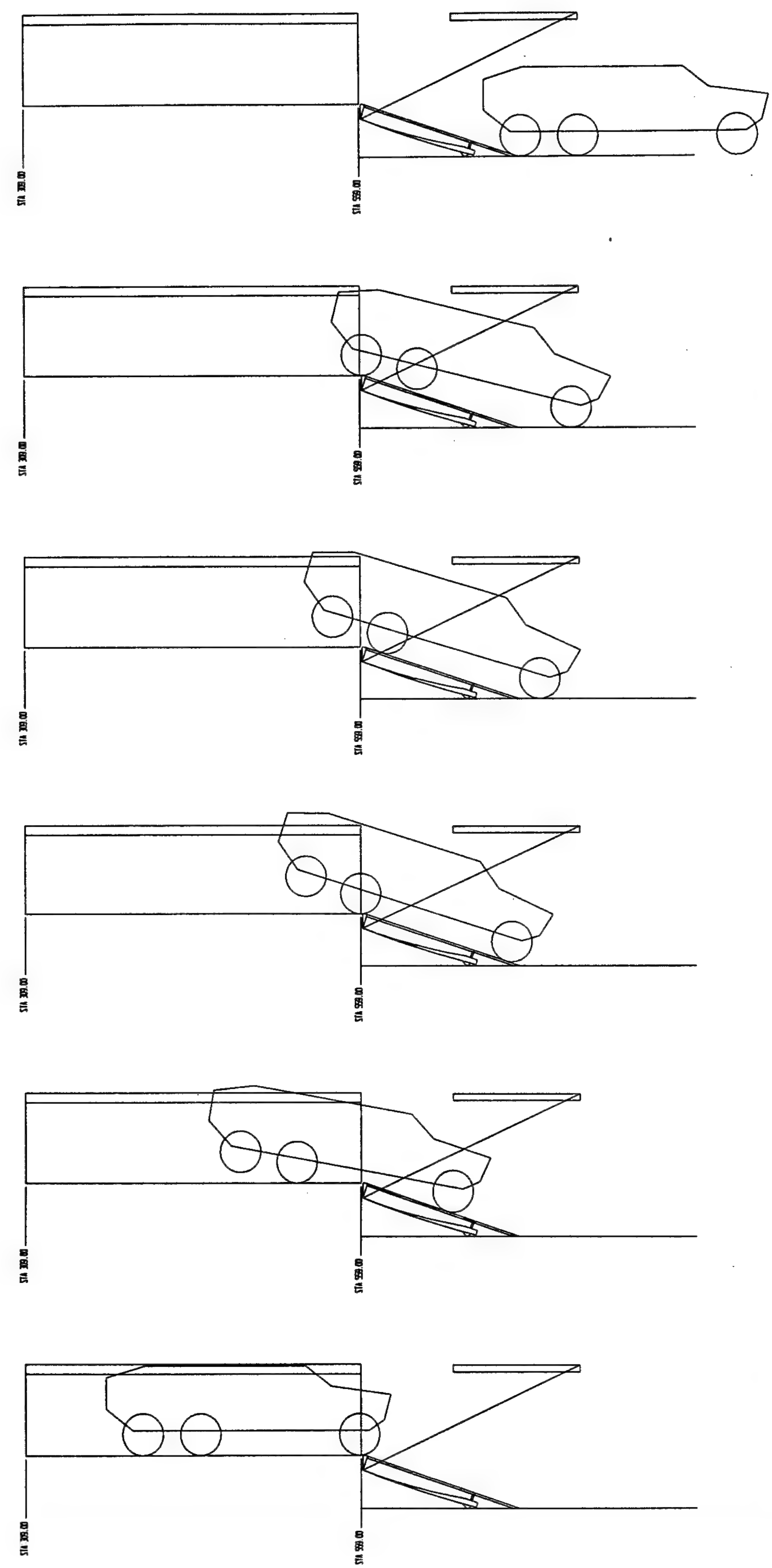
Copy to:
AIR-530P
AIR-5303S
AIR-53033F
AIR-5302

CAD DRAWINGS OF A

NOTIONAL RSTA-V/V-22 INTERFACE

Addendum b.

SEQUENCE 1: NOTIONAL RSTA-V AT 18 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN BACKWARD.



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -

WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 3.8

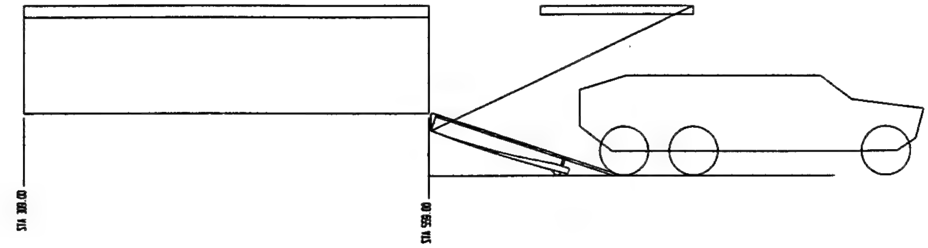
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -3.4

WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -9.0

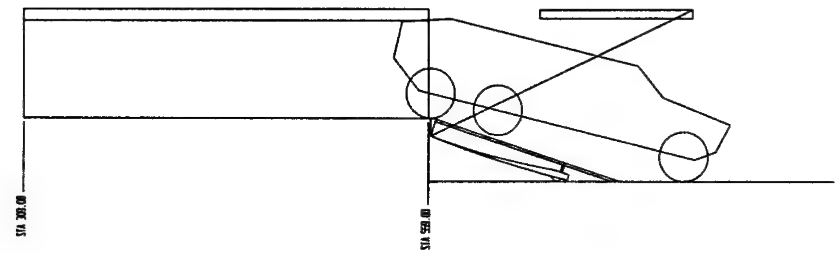
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 8.8
OVERHEAD CLEARANCE: -5.4

WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 1.2

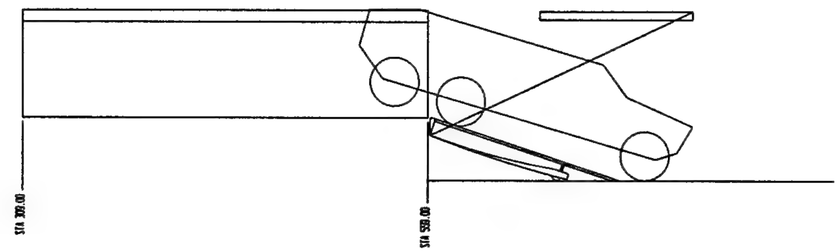
SEQUENCE 2: NOTIONAL RSTA-V AT 15 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN BACKWARD.



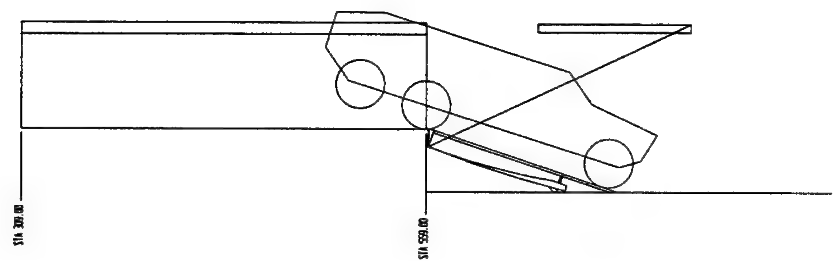
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



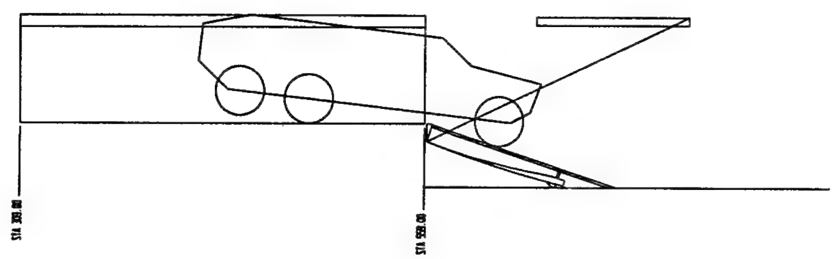
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 6.7



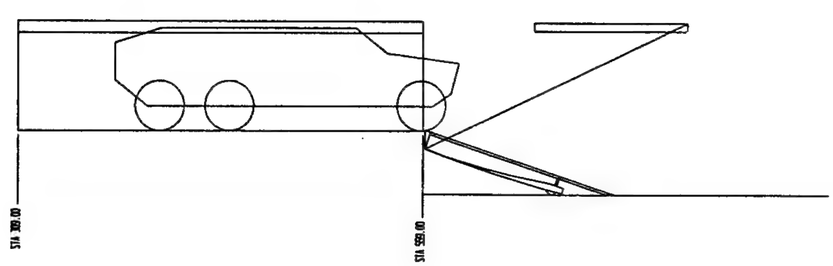
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -0.6



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -6.1

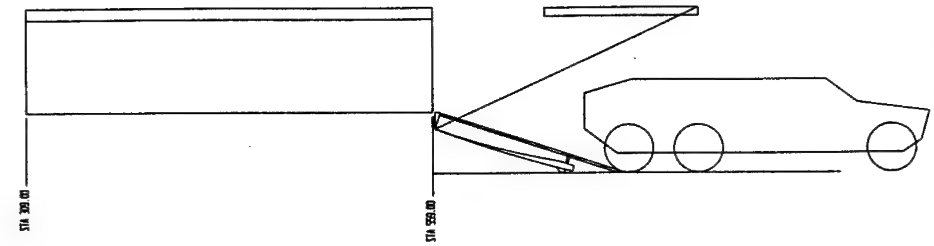


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 6.5
OVERHEAD CLEARANCE: -0.2

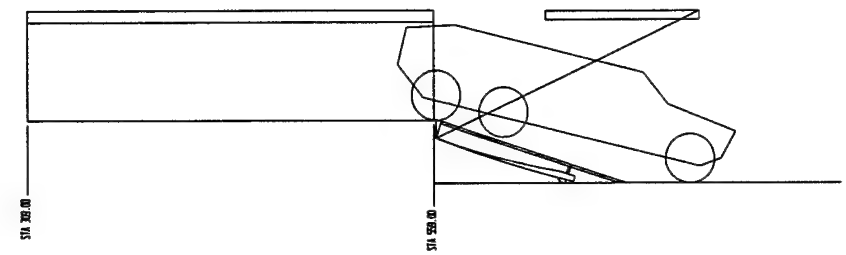


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 4.2

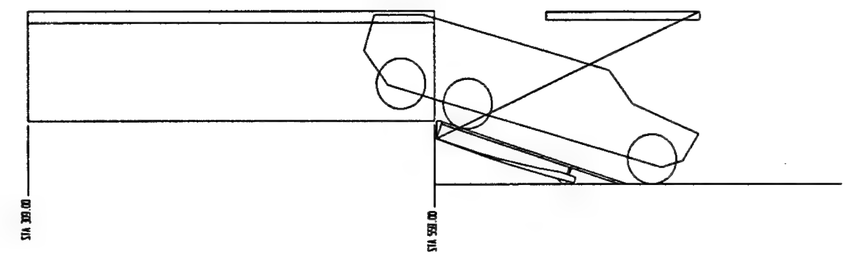
SEQUENCE 3: NOTIONAL RSTA-V AT 12 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN BACKWARD.



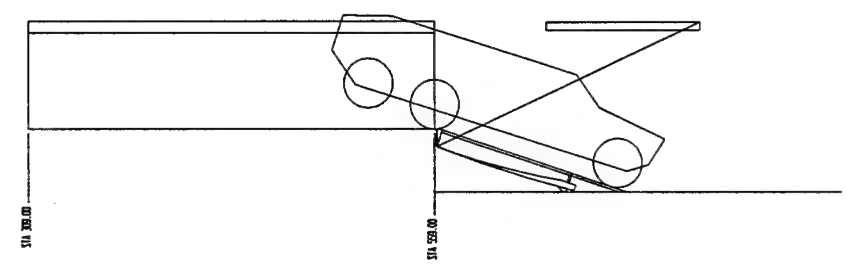
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



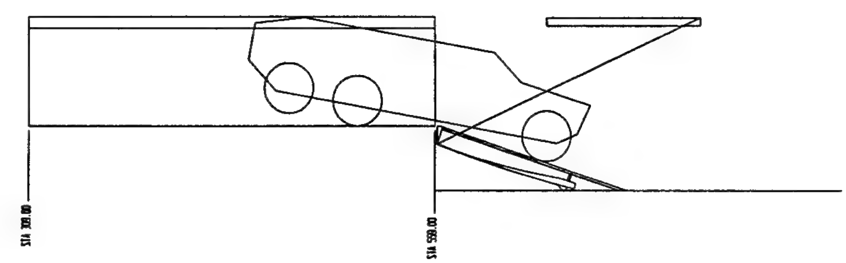
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 9.5



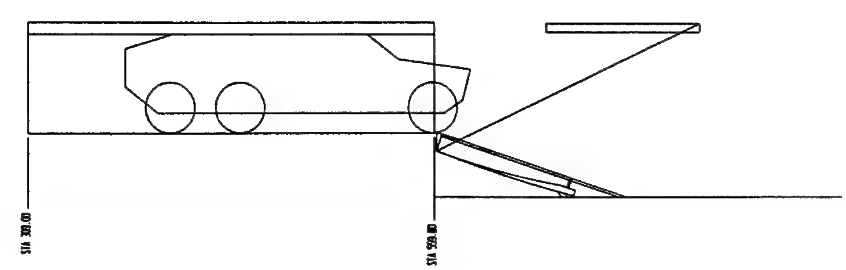
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 2.3



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -3.2

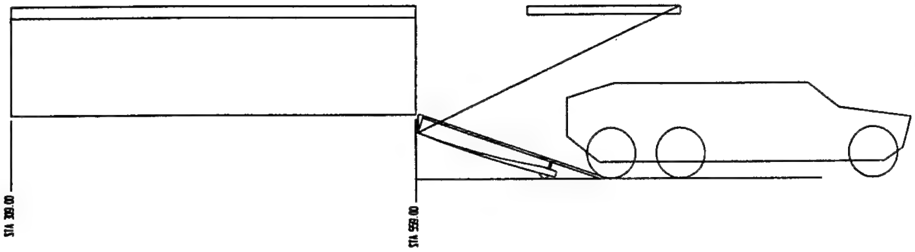


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 2.8
OVERHEAD CLEARANCE: 0.6

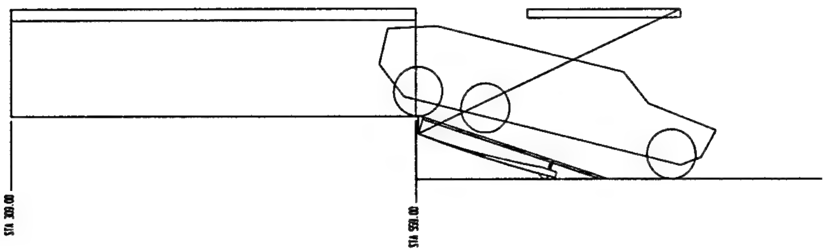


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.2

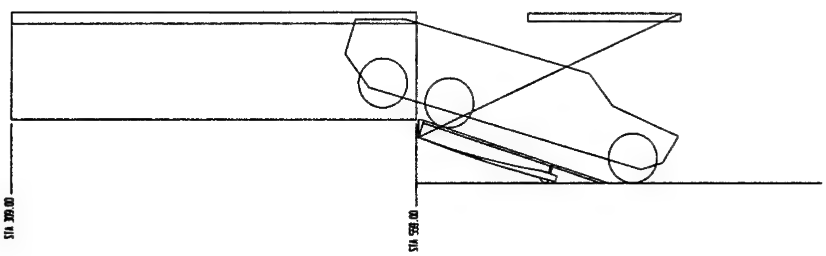
SEQUENCE 4: NOTIONAL RSTA-V AT 10 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN BACKWARD.



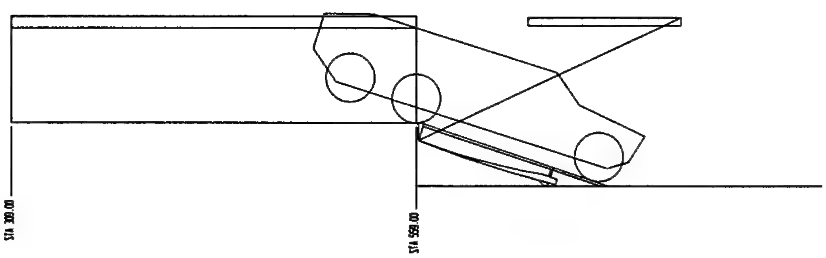
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



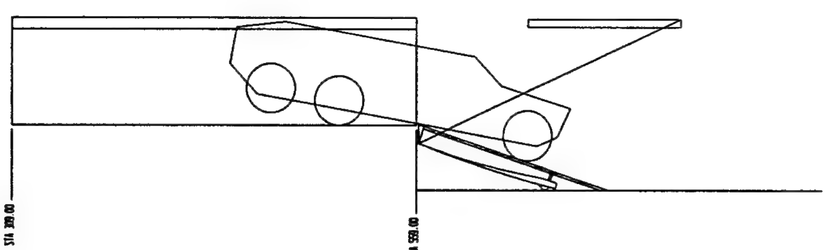
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 11.5



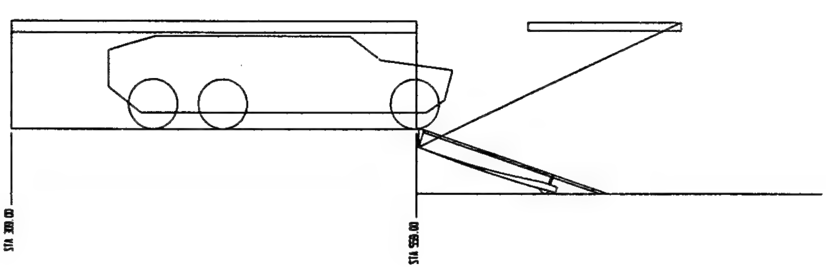
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 4.2



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -1.9

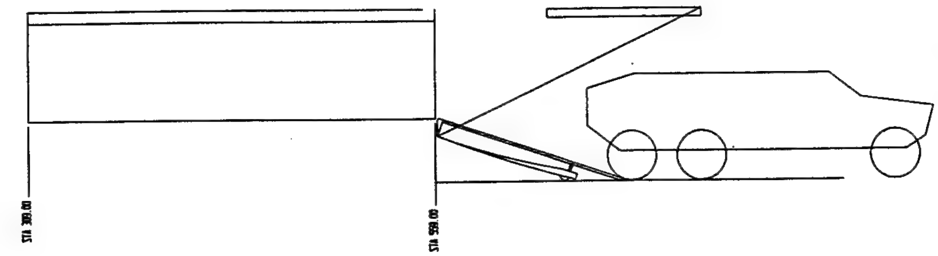


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 0.8
OVERHEAD CLEARANCE: 2.5

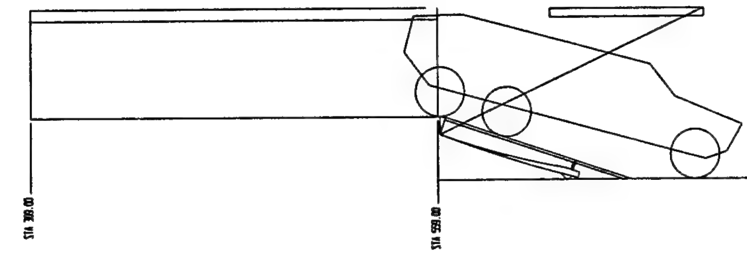


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 9.2

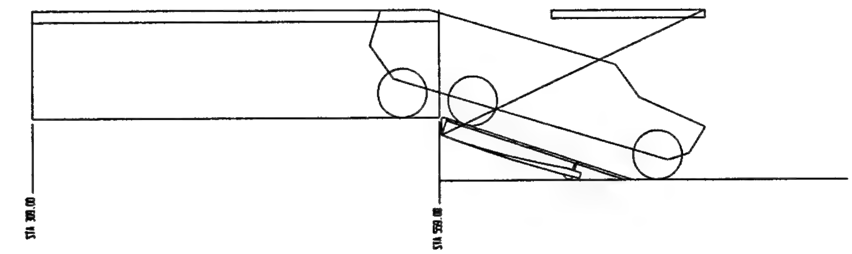
SEQUENCE 5: NOTIONAL RSTA-V AT 18 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN BACKWARD.



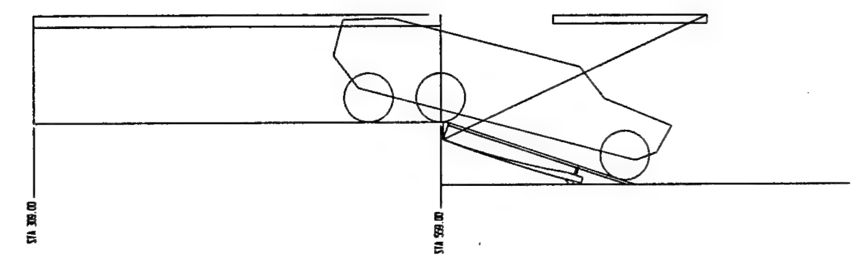
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



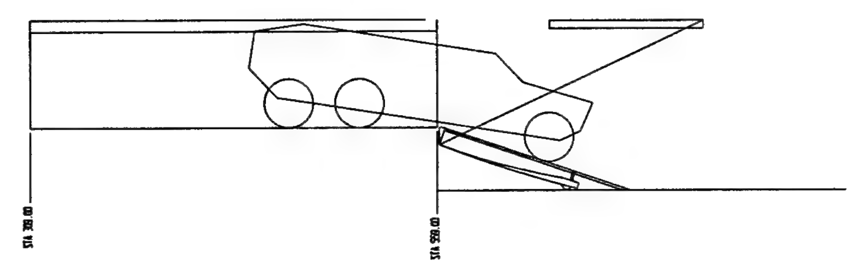
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.55 DROOP
AXLE 3: 0.73 BUMP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 4.7



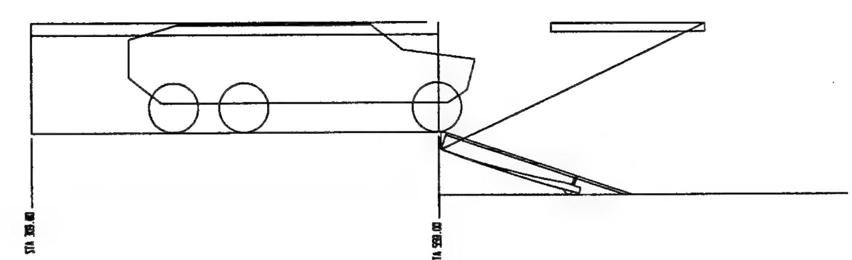
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.67 BUMP
AXLE 3: 3.95 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 0



WHEEL TRAVEL
AXLE 1: 4
AXLE 2: 9.96 BUMP
AXLE 3: 1.24 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 2.1

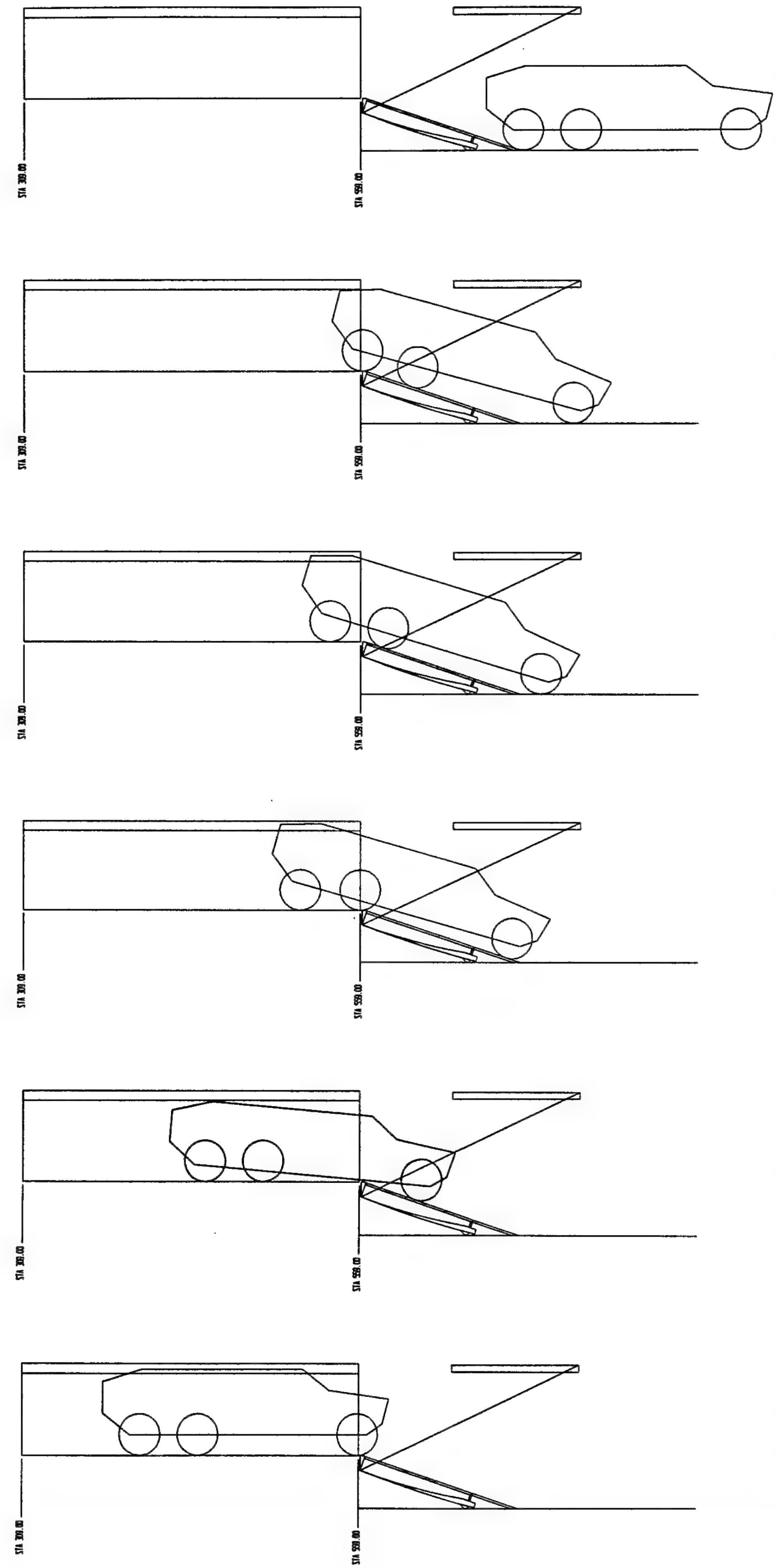


WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 7.1 BUMP
AXLE 3: 0.55 BUMP
BREAKOVER CLEARANCE: 3.0
OVERHEAD CLEARANCE: 2.6



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 1.2

SEQUENCE 6: NOTIONAL RSTA-V AT 15 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN BACKWARD.



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -

WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: .55 DROOP
AXLE 3: .73 BUMP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.4

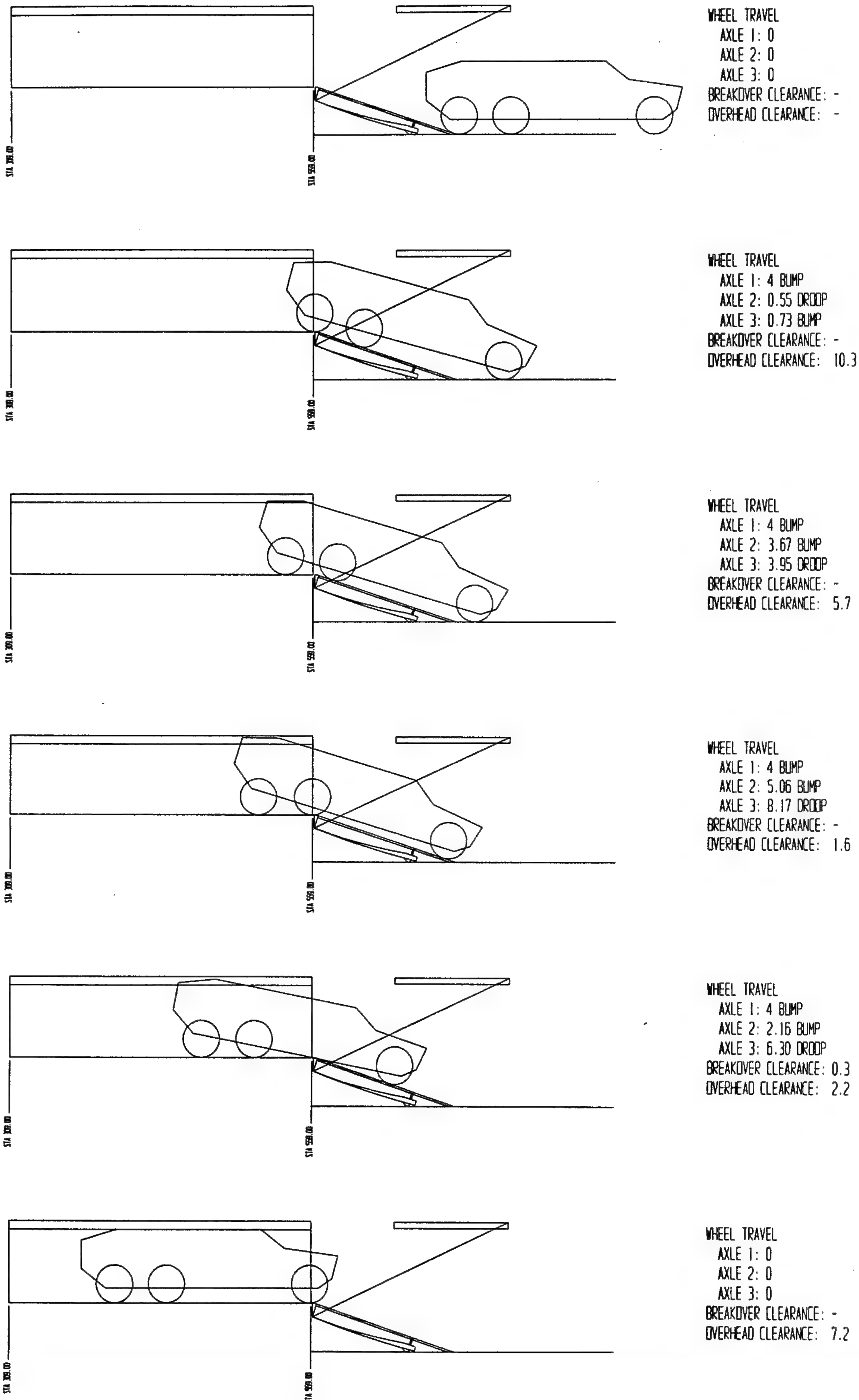
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.67 BUMP
AXLE 3: 3.95 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 2.9

WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 7.50 BUMP
AXLE 3: 4.72 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 1.9

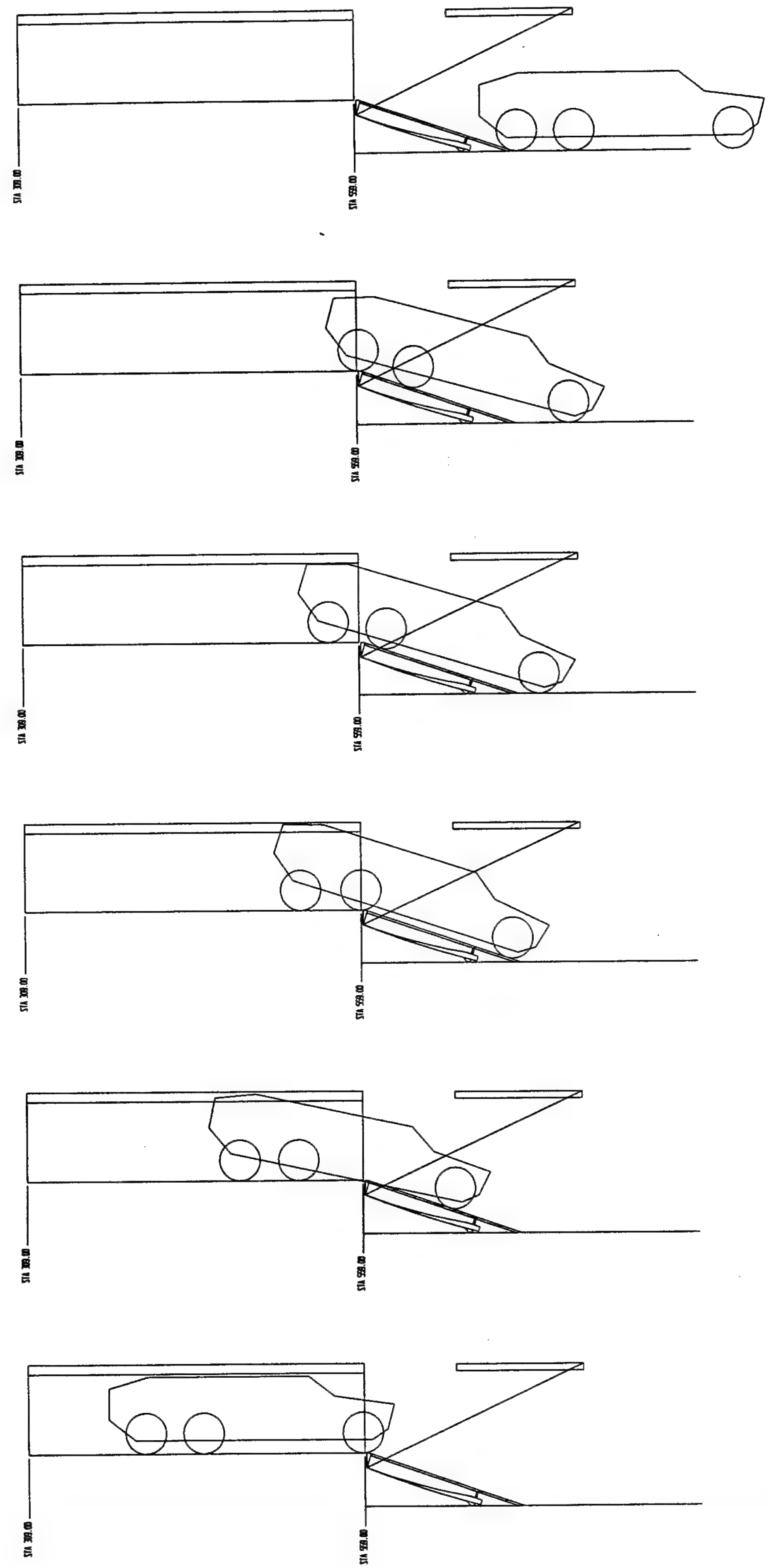
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 7.21 BUMP
AXLE 3: 3.44 BUMP
BREAKOVER CLEARANCE: 1.3
OVERHEAD CLEARANCE: 8.0

WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 4.2

SEQUENCE 7: NOTIONAL RSTA-V AT 12 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN BACKWARD.



SEQUENCE 8: NOTIONAL RSTA-V AT 10 INCH RIDE HEIGHT
WITH WHEEL TRAVEL ROLLING IN BACKWARD.



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -

WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.55 DROOP
AXLE 3: 0.73 BUMP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 12.2

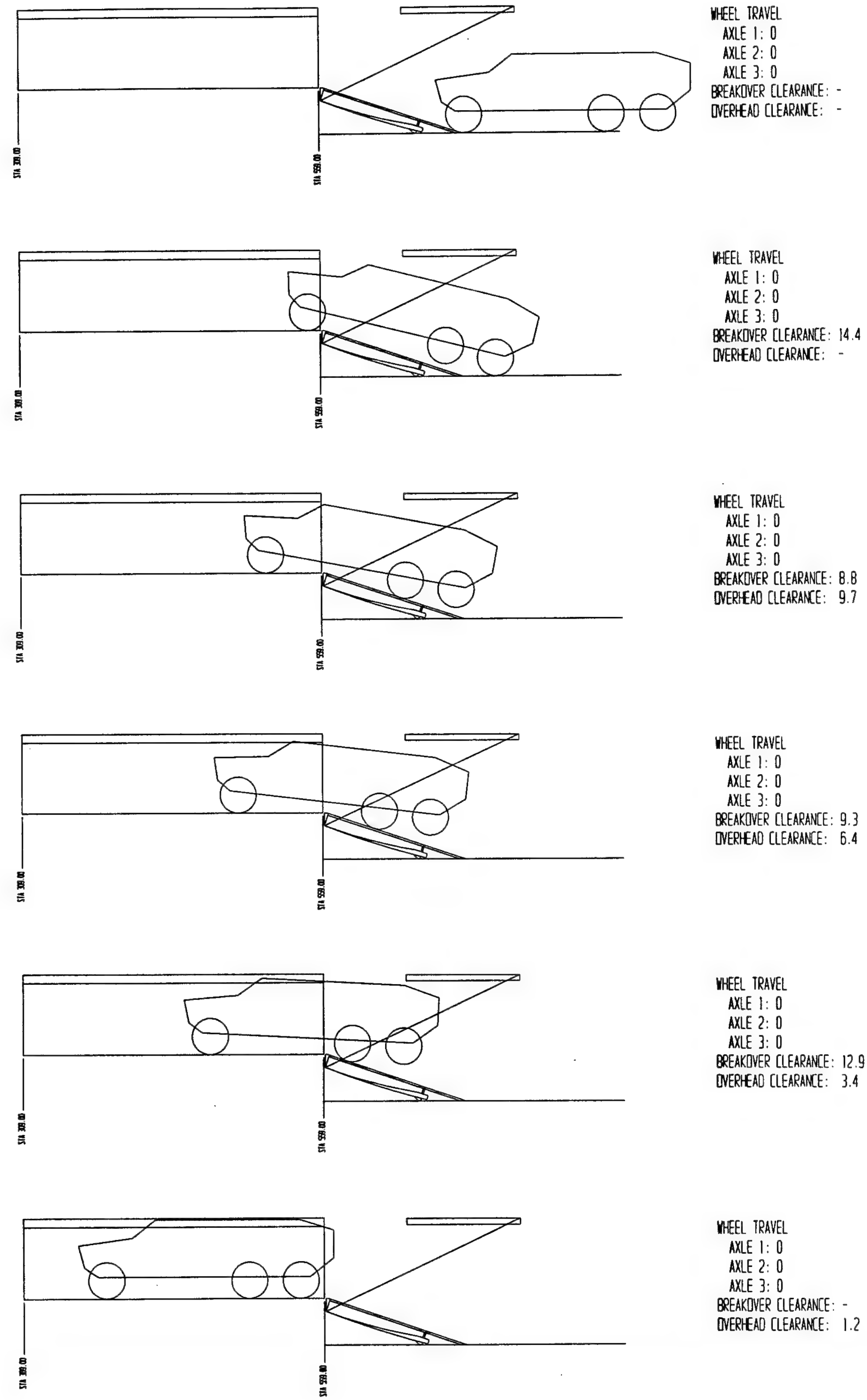
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.67 BUMP
AXLE 3: 3.95 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.7

WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.44 BUMP
AXLE 3: 10.44 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 1.1

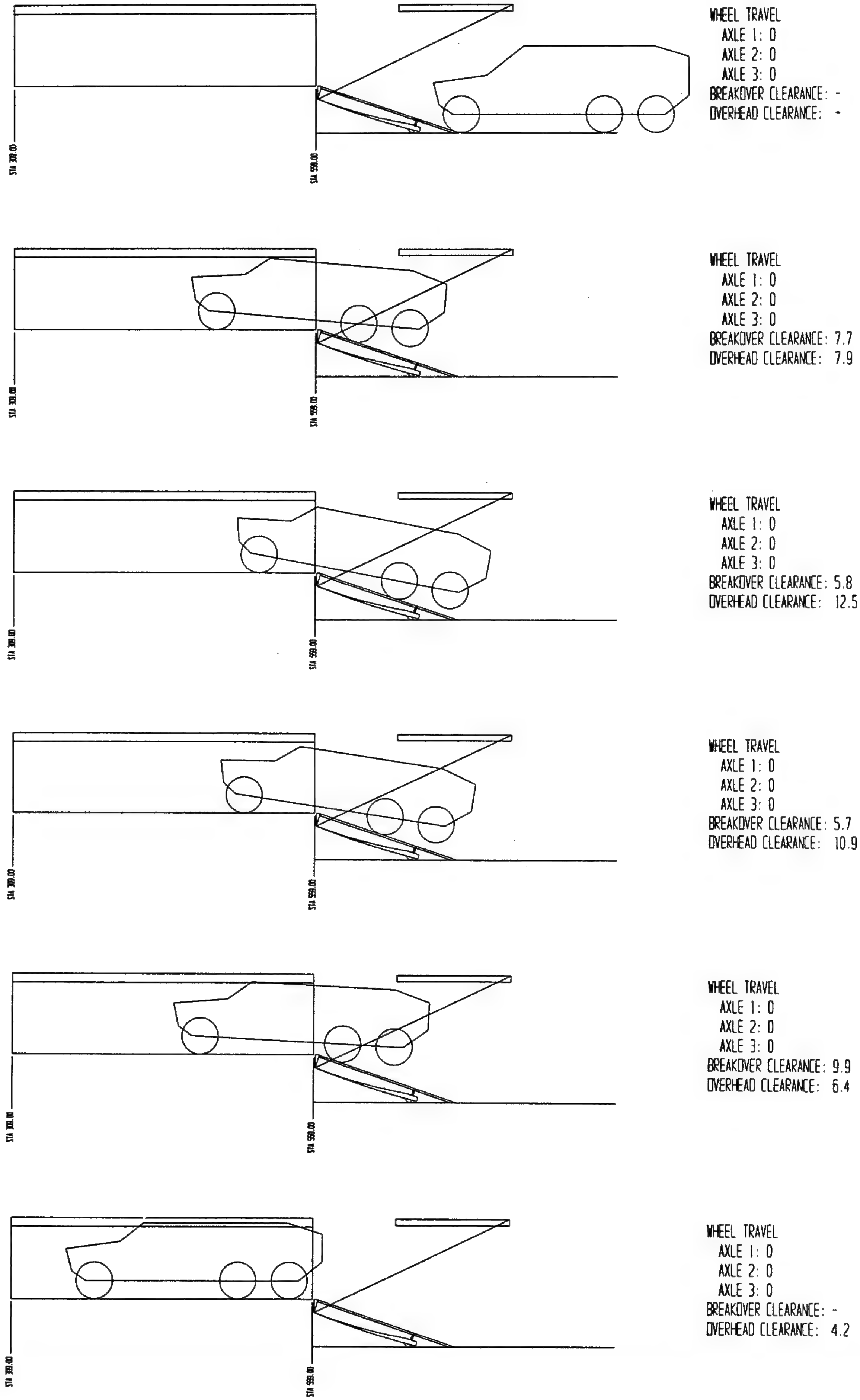
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.53 BUMP
AXLE 3: 8.58 DROOP
BREAKOVER CLEARANCE: -1.4
OVERHEAD CLEARANCE: 2.1

WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 9.2

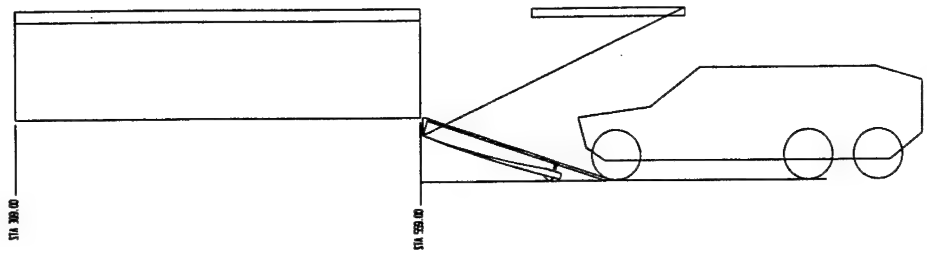
SEQUENCE 9: NOTIONAL RSTA-V AT 18 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN FORWARD.



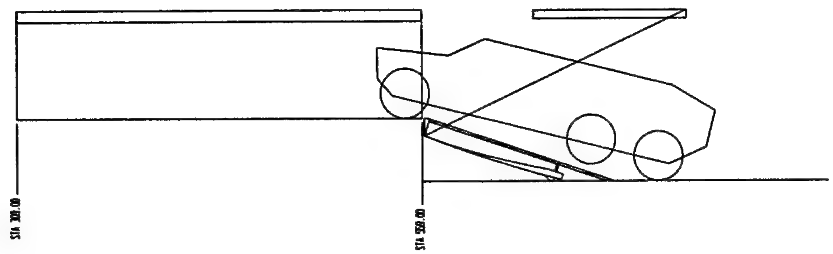
SEQUENCE 10: NOTIONAL RSTA-V AT 15 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN FORWARD.



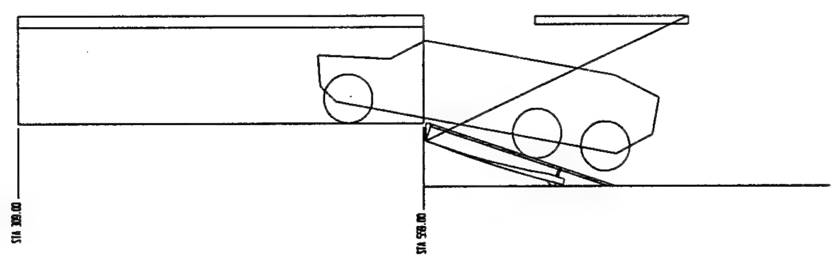
SEQUENCE 11: NOTIONAL RSTA-V AT 12 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN FORWARD.



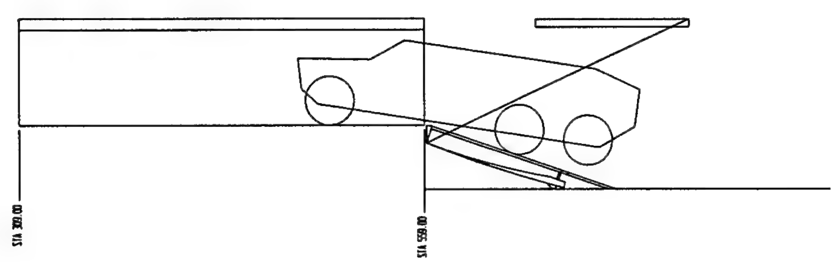
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



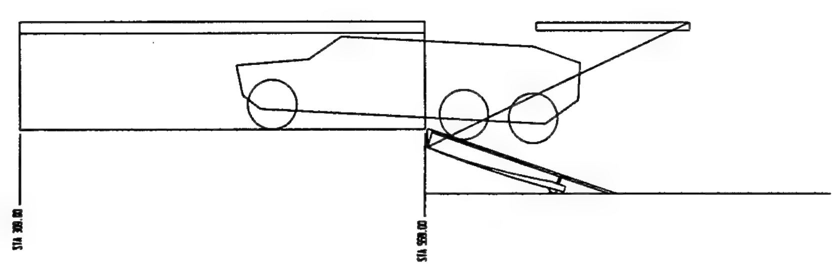
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 8.4
OVERHEAD CLEARANCE: -



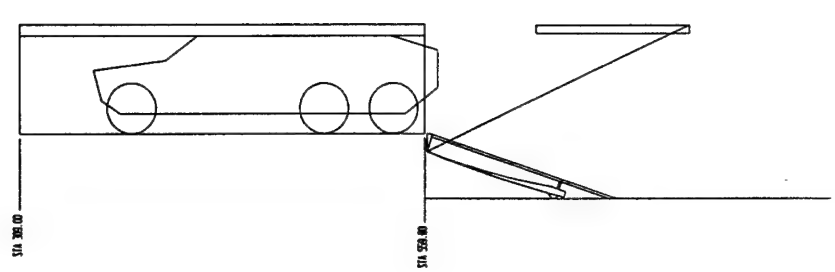
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 2.8
OVERHEAD CLEARANCE: 15.4



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 2.7
OVERHEAD CLEARANCE: 13.8

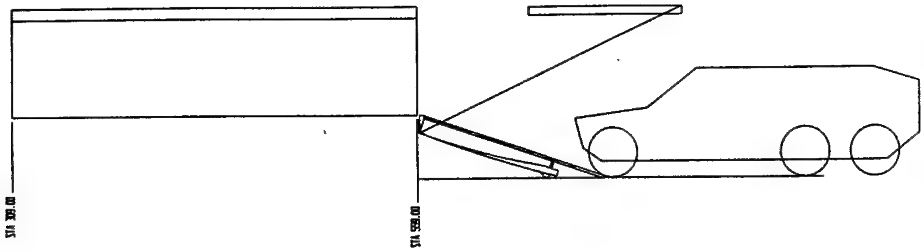


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 6.9
OVERHEAD CLEARANCE: 9.4

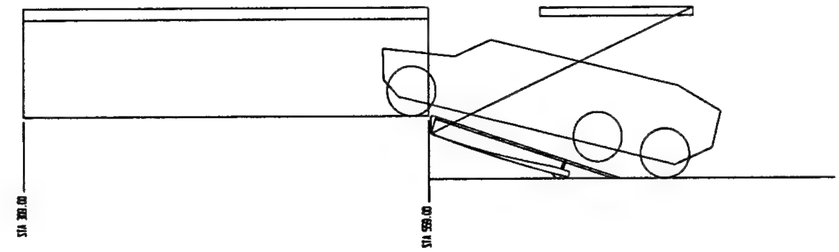


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.2

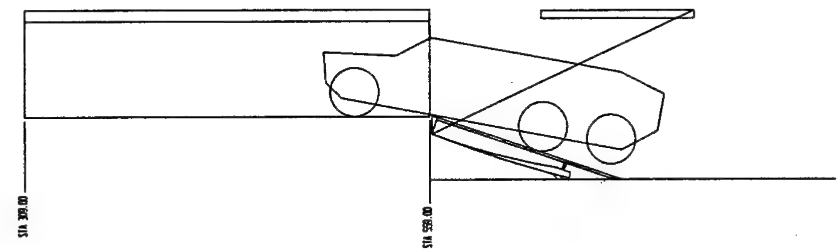
SEQUENCE 12: NOTIONAL RSTA-V AT 10 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN FORWARD.



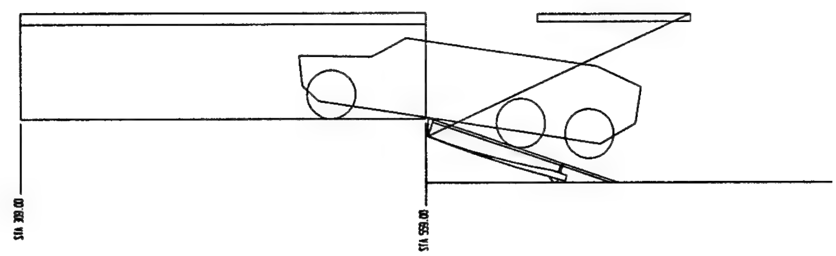
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



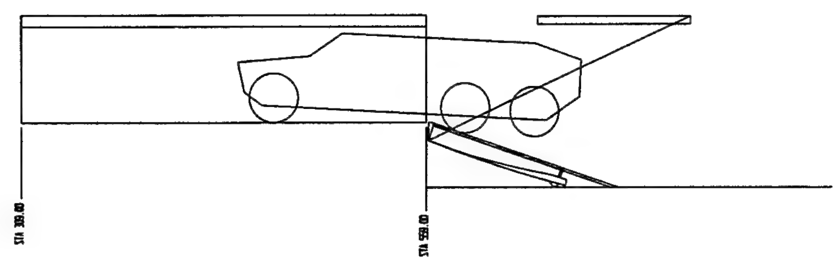
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 6.4
OVERHEAD CLEARANCE: -



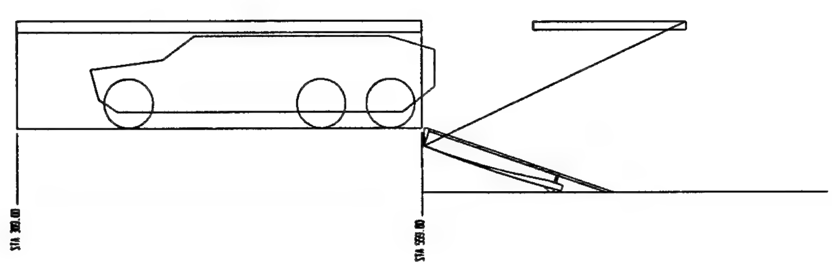
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 0.8
OVERHEAD CLEARANCE: 17.3



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 0.7
OVERHEAD CLEARANCE: 15.8

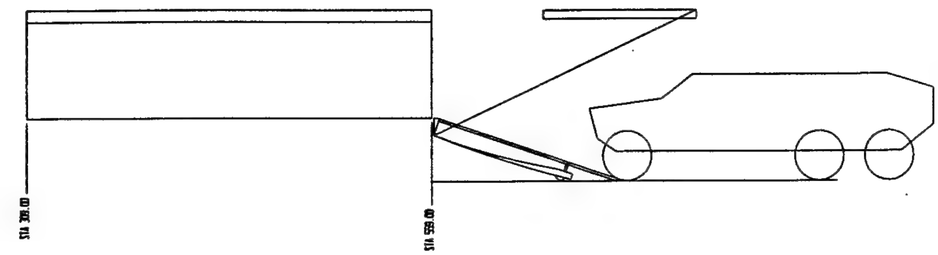


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 4.9
OVERHEAD CLEARANCE: 11.4

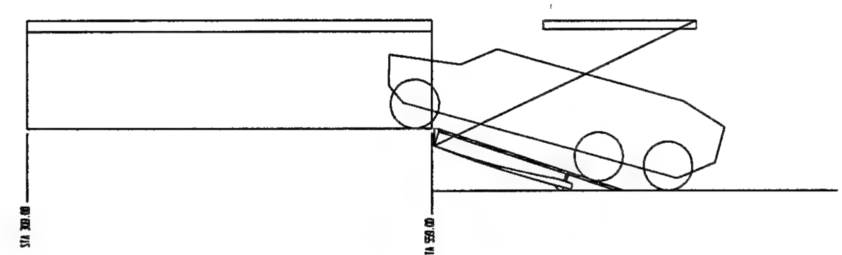


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 9.2

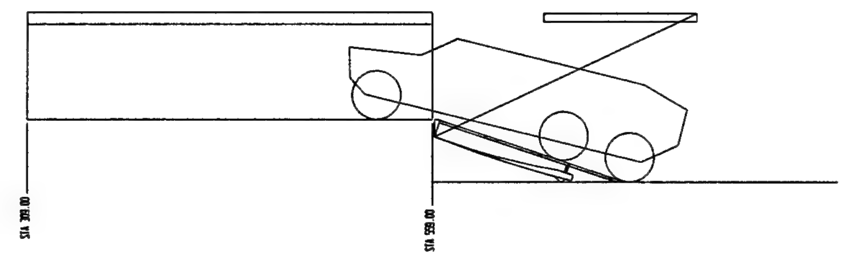
SEQUENCE 13: NOTIONAL RSTA-V AT 18 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN FORWARD.



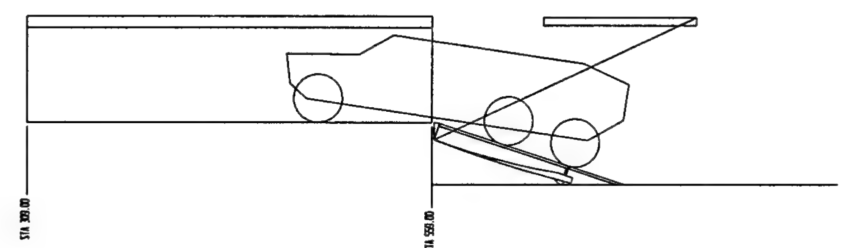
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



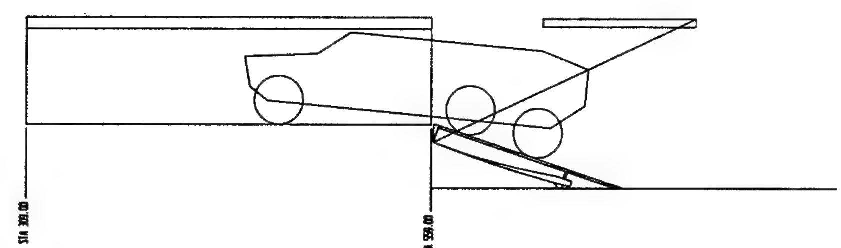
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 2.85 BUMP
AXLE 3: 8.63 BUMP
BREAKOVER CLEARANCE: 9.9
OVERHEAD CLEARANCE: -



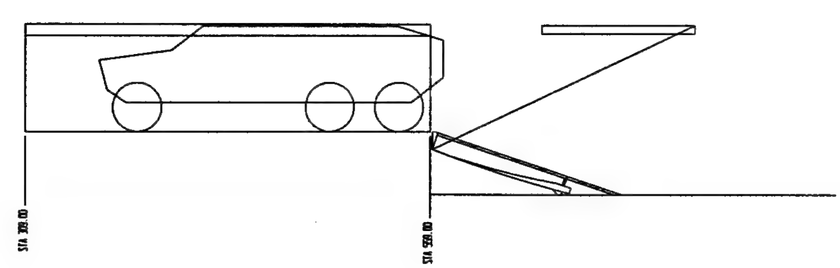
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 7.09 BUMP
AXLE 3: 3.98 BUMP
BREAKOVER CLEARANCE: 4.6
OVERHEAD CLEARANCE: 22.6



WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 7.59 BUMP
AXLE 3: 0.02 BUMP
BREAKOVER CLEARANCE: 3.1
OVERHEAD CLEARANCE: 11.7

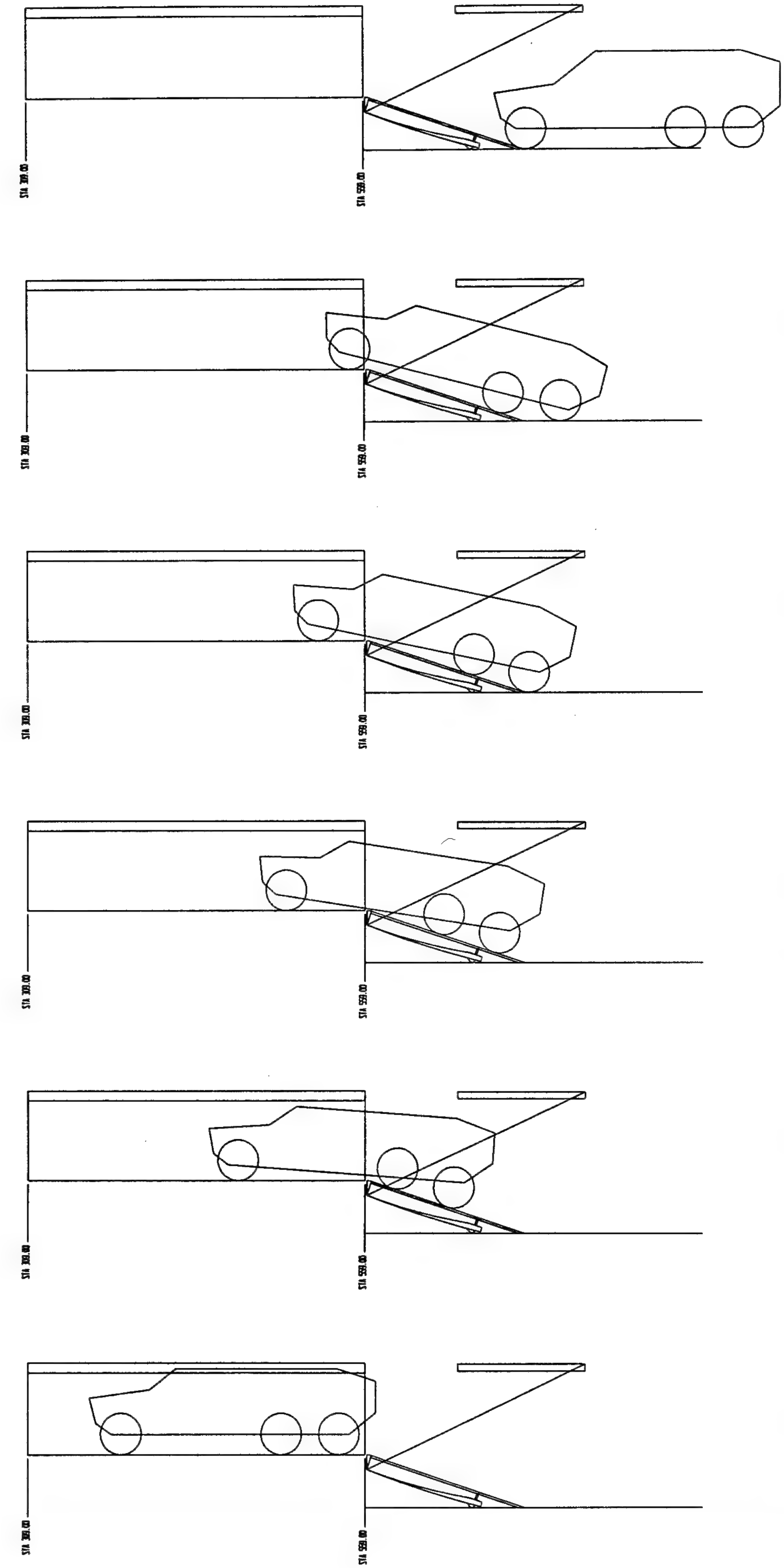


WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 9.04 BUMP
AXLE 3: 0.94 DROOP
BREAKOVER CLEARANCE: 4.8
OVERHEAD CLEARANCE: 9.3



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 1.2

SEQUENCE 14: NOTIONAL RSTA-V AT 15 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN FORWARD.



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -

WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.35 BUMP
AXLE 3: 5.21 BUMP
BREAKOVER CLEARANCE: 7.2
OVERHEAD CLEARANCE: 33.7

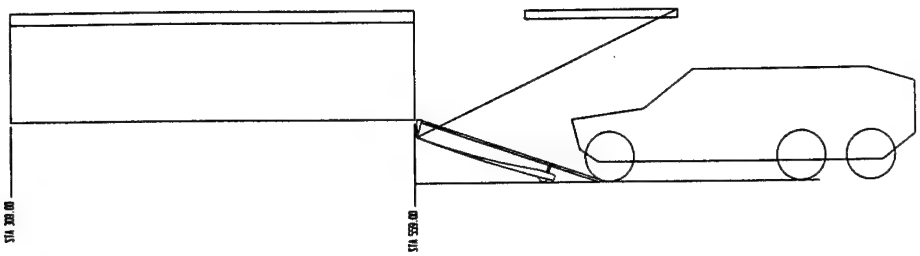
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 2.83 BUMP
AXLE 3: 1.80 DROOP
BREAKOVER CLEARANCE: 3.1
OVERHEAD CLEARANCE: 22.3

WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 4.44 BUMP
AXLE 3: 2.87 DROOP
BREAKOVER CLEARANCE: 1.5
OVERHEAD CLEARANCE: 15.0

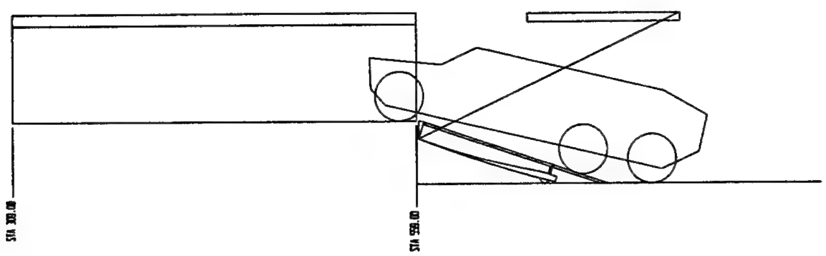
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 6.61 BUMP
AXLE 3: 4.30 DROOP
BREAKOVER CLEARANCE: 3.8
OVERHEAD CLEARANCE: 11.4

WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 4.2

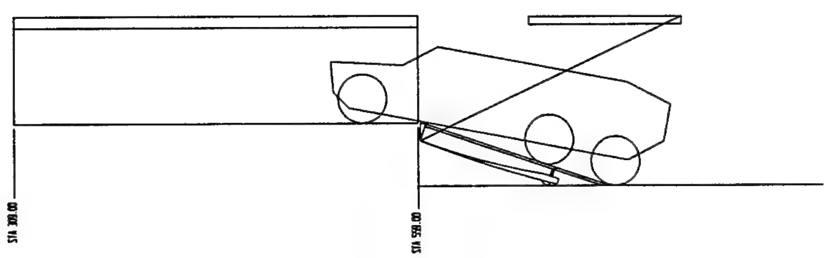
SEQUENCE 15: NOTIONAL RSTA-V AT 12 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN FORWARD.



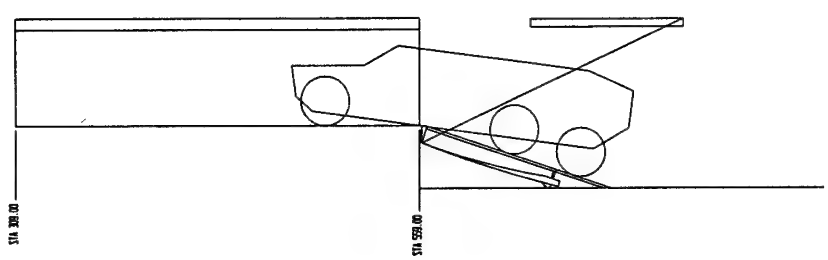
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



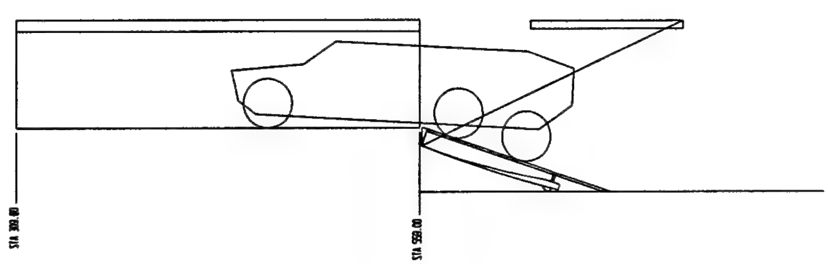
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 2.16 DROOP
AXLE 3: 1.80 BUMP
BREAKOVER CLEARANCE: 4.6
OVERHEAD CLEARANCE: -



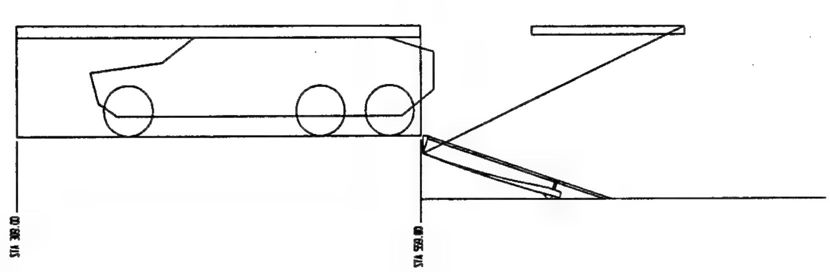
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.39 BUMP
AXLE 3: 5.90 DROOP
BREAKOVER CLEARANCE: 0.9
OVERHEAD CLEARANCE: 23.1



WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 1.99 BUMP
AXLE 3: 6.23 DROOP
BREAKOVER CLEARANCE: -0.3
OVERHEAD CLEARANCE: 17.0

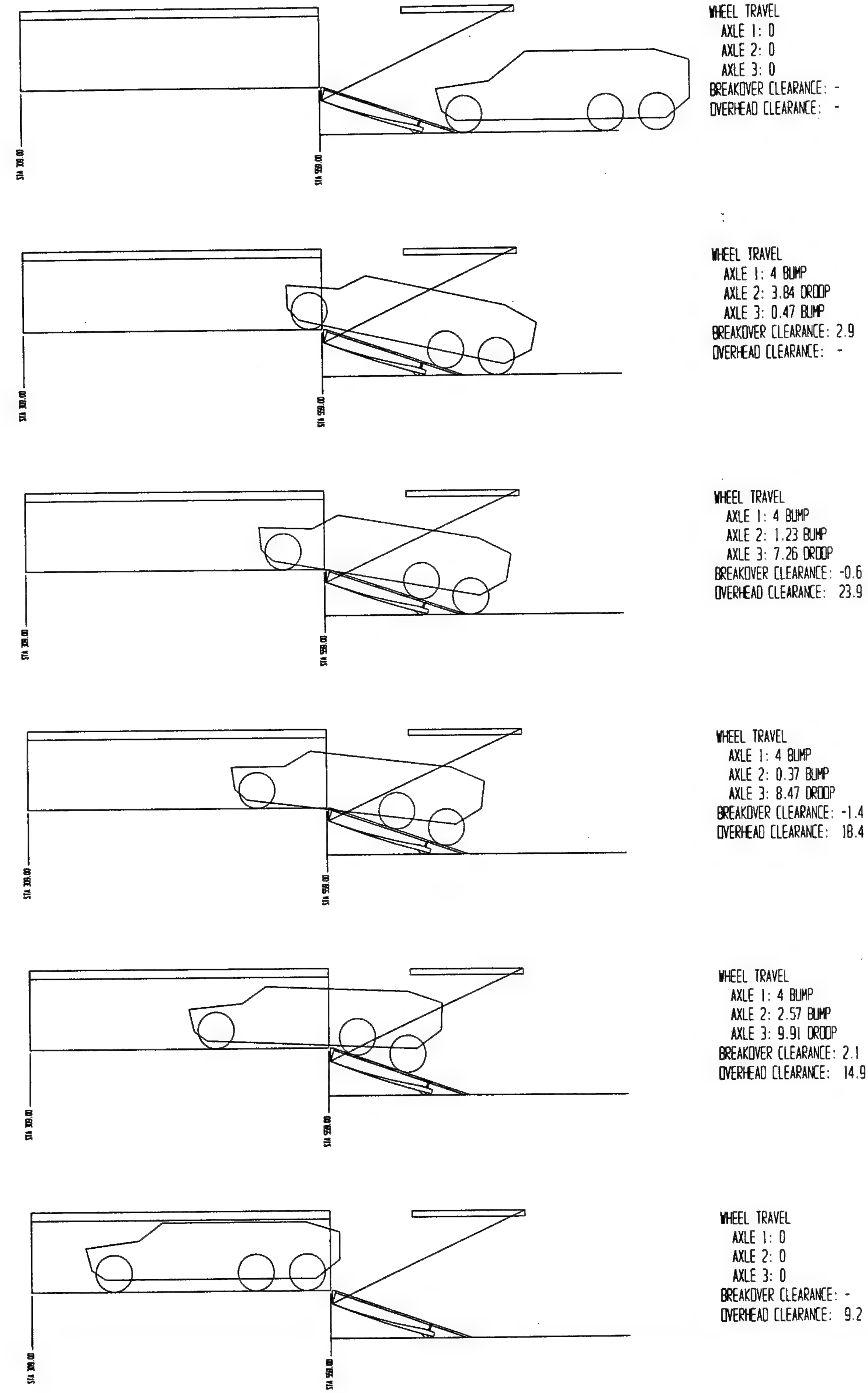


WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 4.19 BUMP
AXLE 3: 7.66 DROOP
BREAKOVER CLEARANCE: 2.8
OVERHEAD CLEARANCE: 13.5

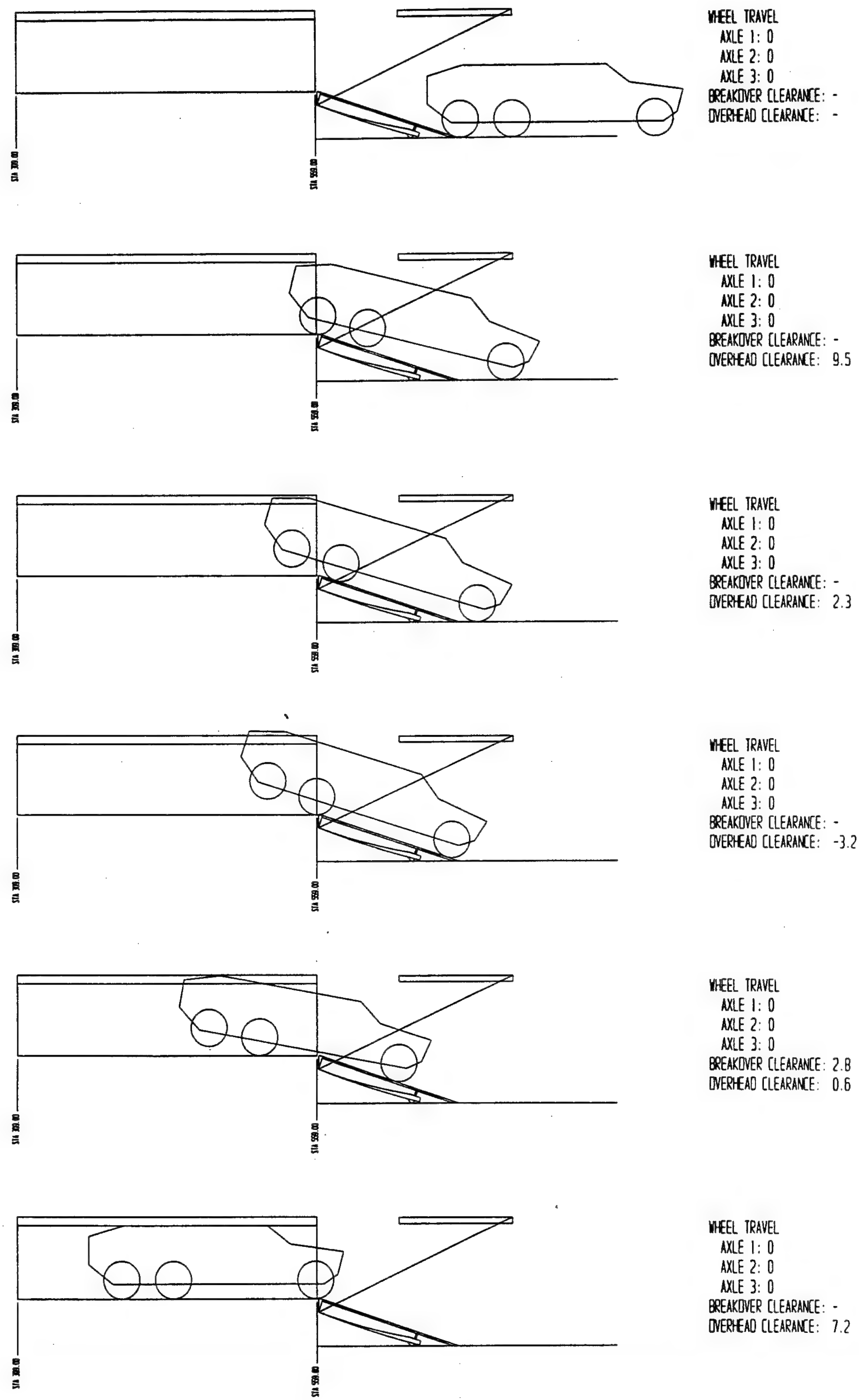


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.2

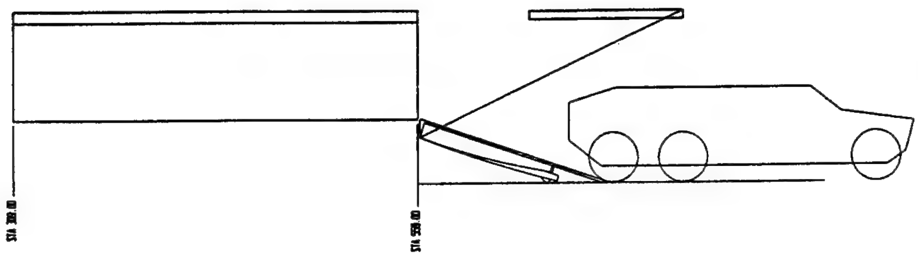
SEQUENCE 16: NOTIONAL RSTA-V AT 10 INCH RIDE HEIGHT
WITH WHEEL TRAVEL ROLLING IN FORWARD.



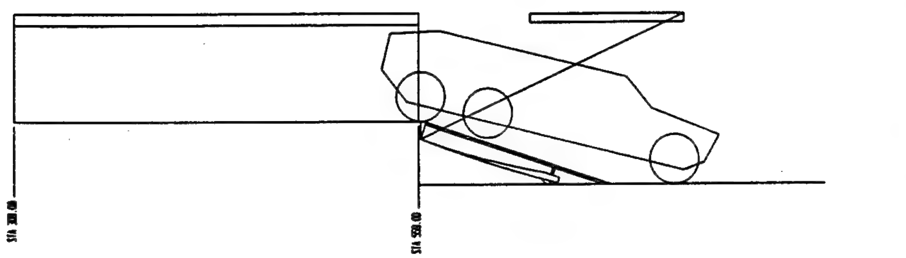
SEQUENCE 3: NOTIONAL RS_{1A}-V AT 12 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN BACKWARD.



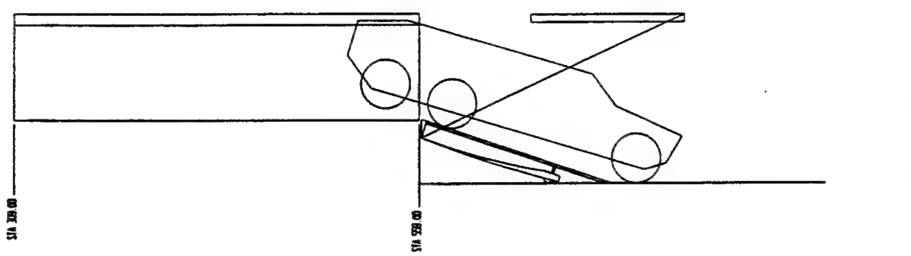
SEQUENCE 4: NOTIONAL RSTA-V AT 10 INCH RIDE HEIGHT, WITH NO WHEEL TRAVEL ROLLING IN BACKWARD.



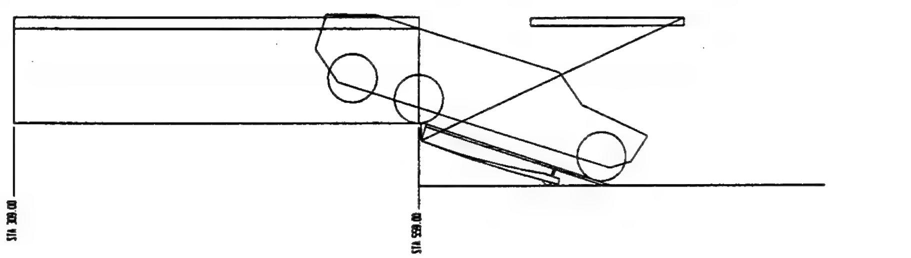
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



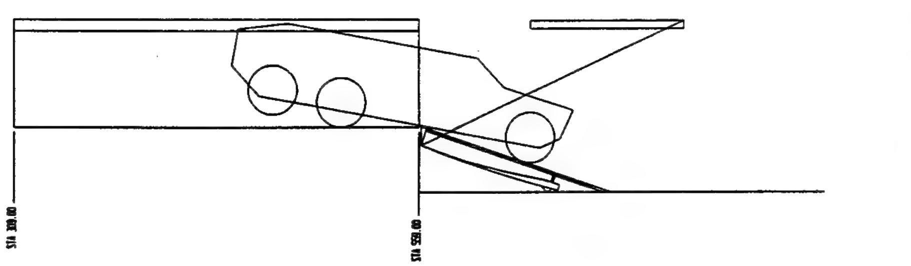
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 11.5



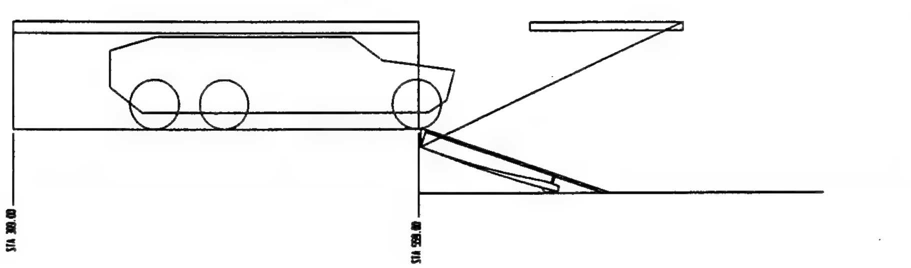
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 4.2



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -1.9

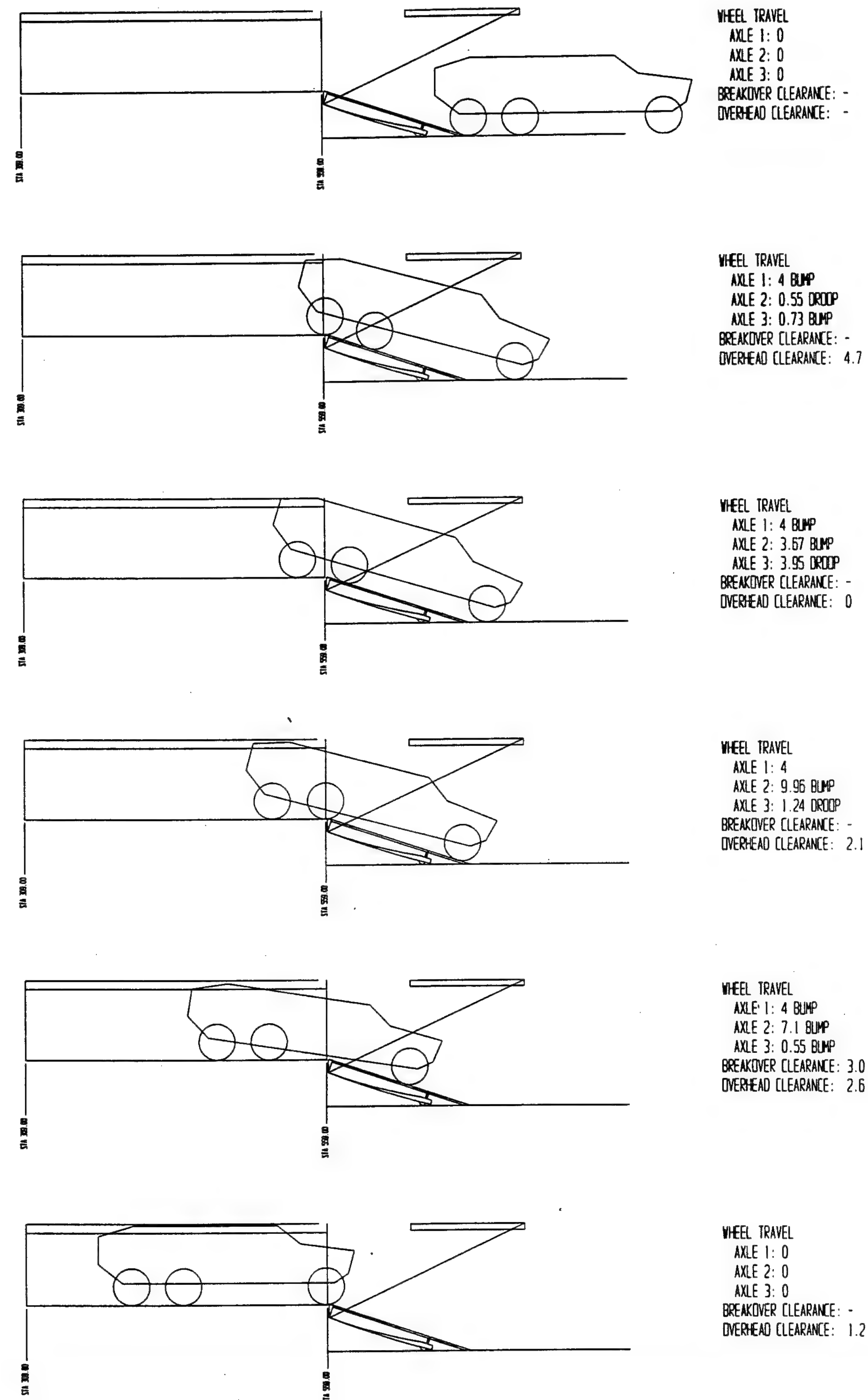


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 0.8
OVERHEAD CLEARANCE: 2.5

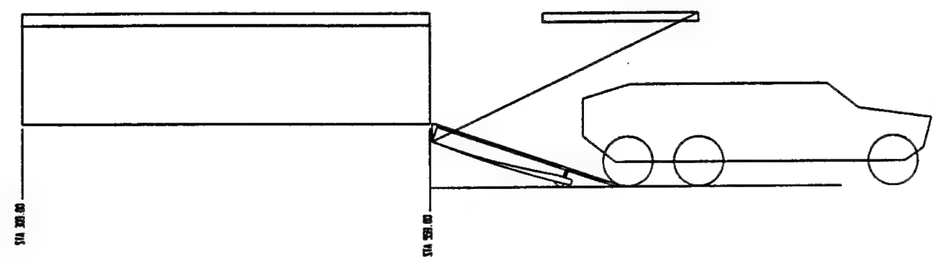


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 9.2

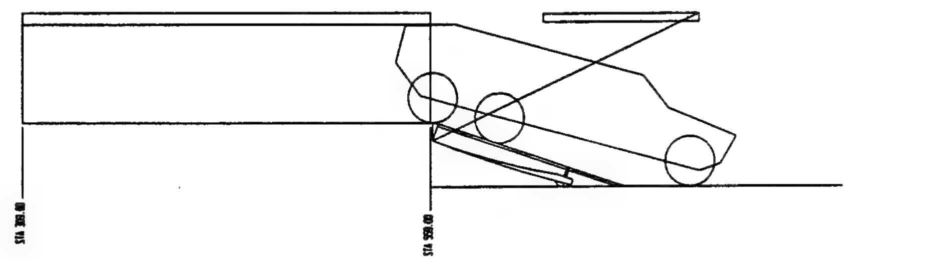
SEQUENCE 5: NOTIONAL RSTA-V AT 18 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN BACKWARD.



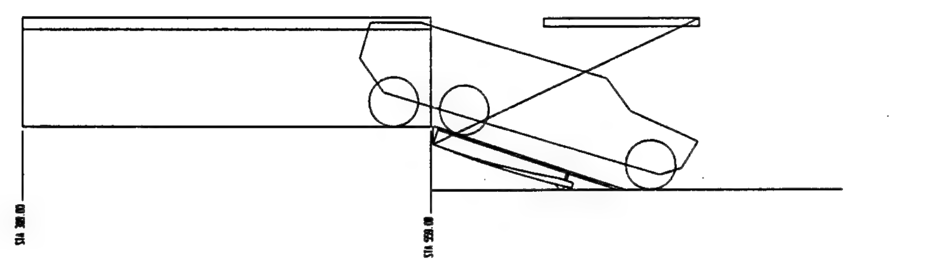
SEQUENCE 6: NOTIONAL RSTA-V AT 15 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN BACKWARD.



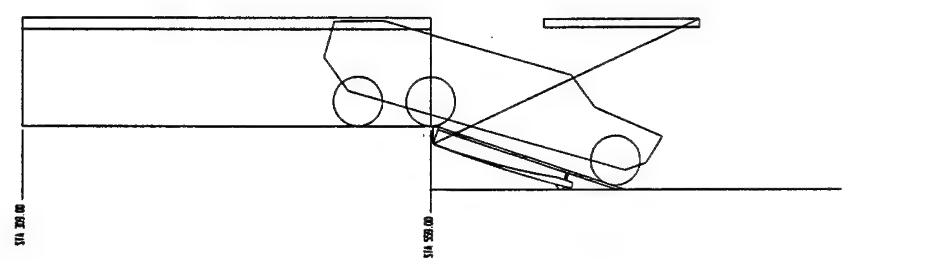
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



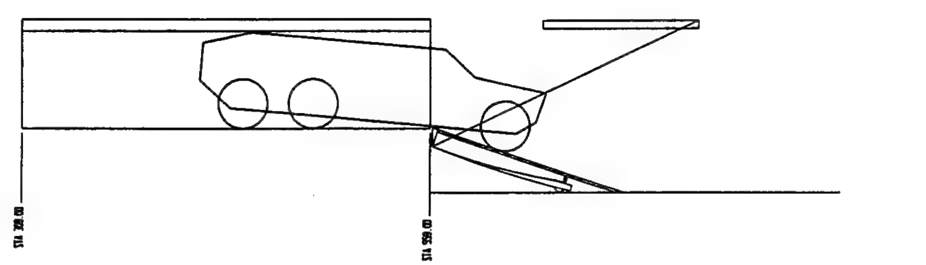
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: .55 DROOP
AXLE 3: .73 BUMP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.4



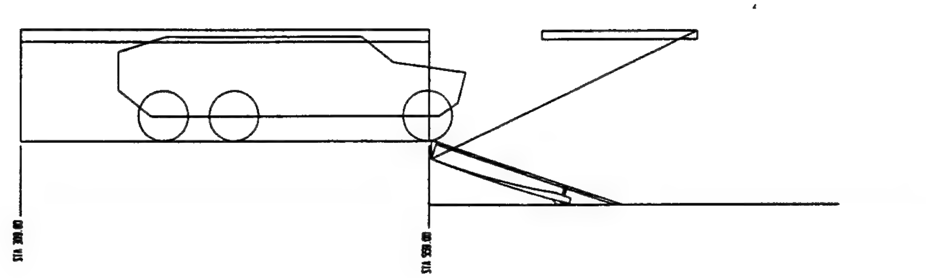
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.67 BUMP
AXLE 3: 3.95 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 2.9



WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 7.50 BUMP
AXLE 3: 4.72 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 1.9

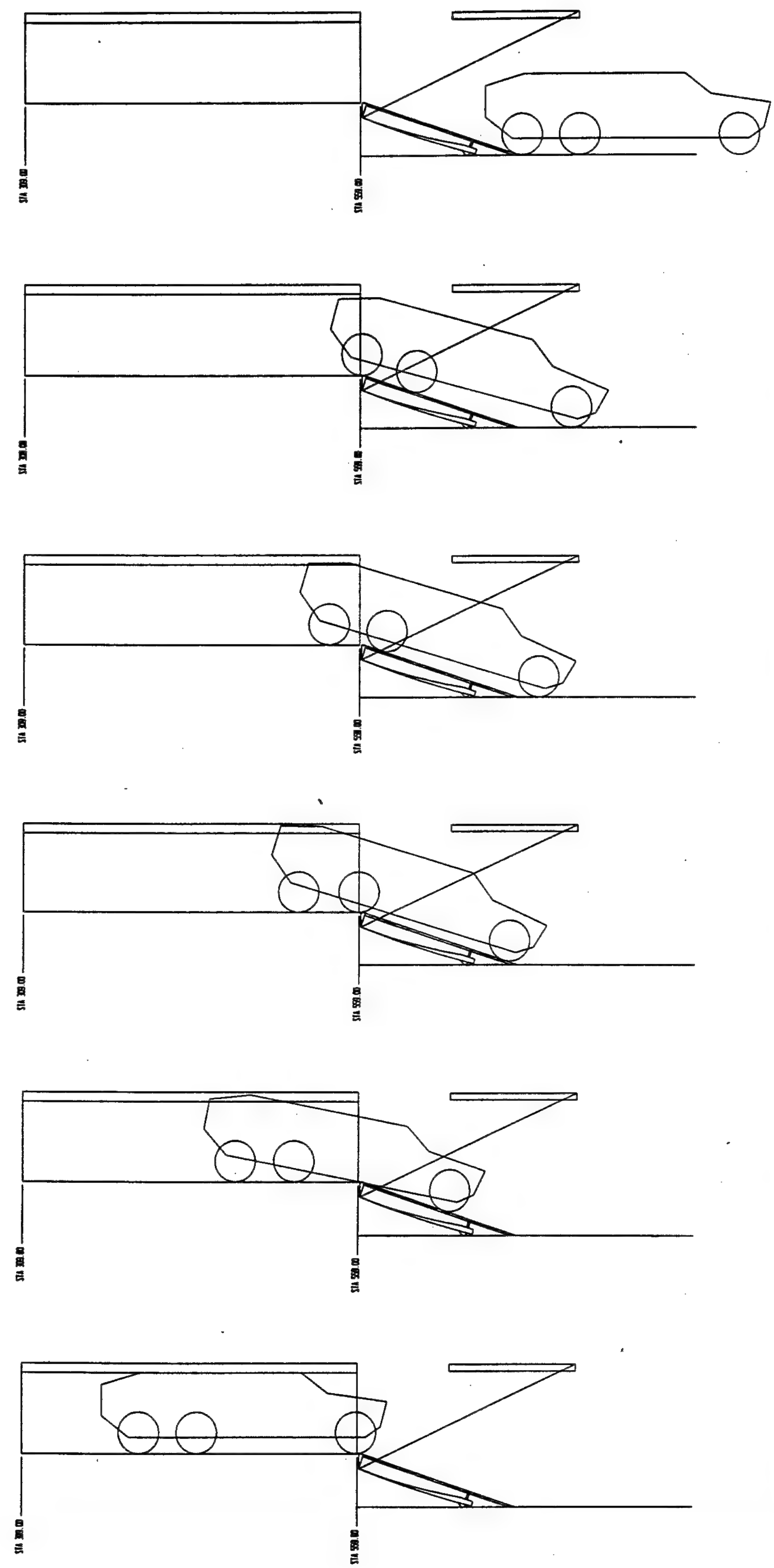


WHEEL TRAVEL.
AXLE 1: 4 BUMP
AXLE 2: 7.21 BUMP
AXLE 3: 3.44 BUMP
BREAKOVER CLEARANCE: 1.3
OVERHEAD CLEARANCE: 8.0



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 4.2

SEQUENCE 7: NOTIONAL RS1A-V AT 12 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN BACKWARD.



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -

WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.55 DROOP
AXLE 3: 0.73 BUMP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 10.3

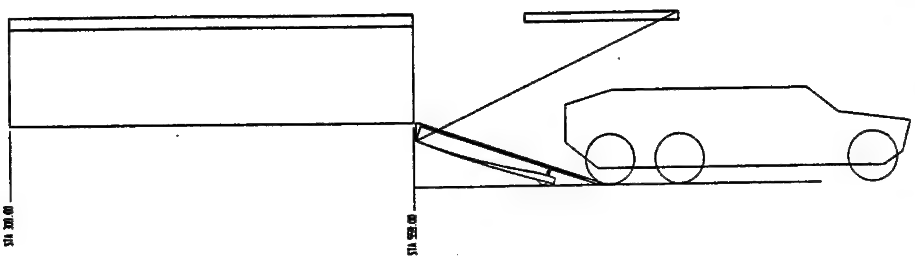
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.67 BUMP
AXLE 3: 3.95 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 5.7

WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 5.06 BUMP
AXLE 3: 8.17 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 1.6

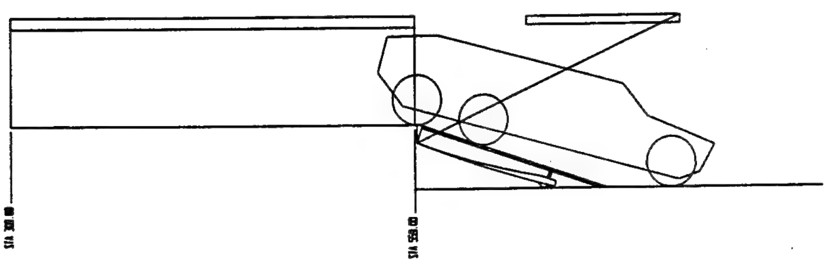
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 2.16 BUMP
AXLE 3: 6.30 DROOP
BREAKOVER CLEARANCE: 0.3
OVERHEAD CLEARANCE: 2.2

WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.2

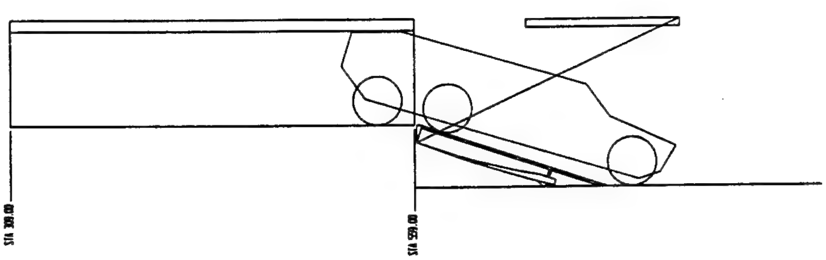
SEQUENCE 8: NOTIONAL RST A-V AT 10 INCH RIDE HEIGHT, WITH WHEEL TRAVEL ROLLING IN BACKWARD.



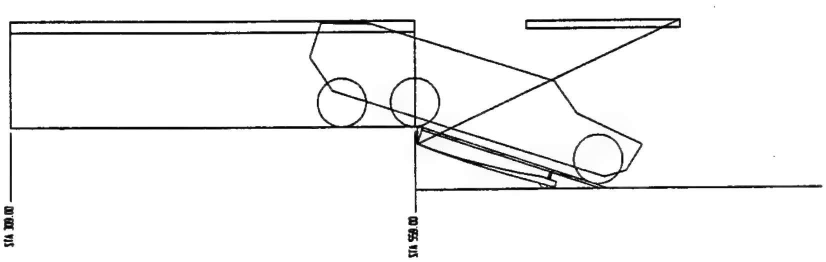
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



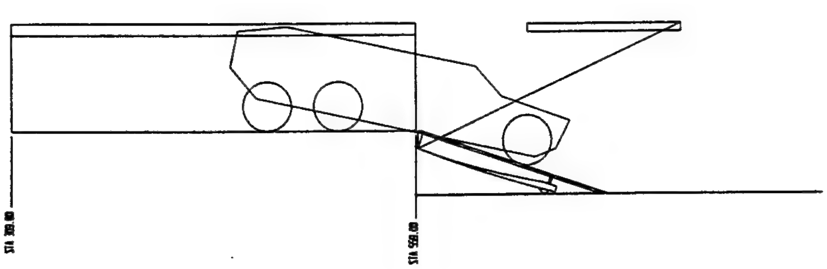
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.55 DROOP
AXLE 3: 0.73 BUMP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 12.2



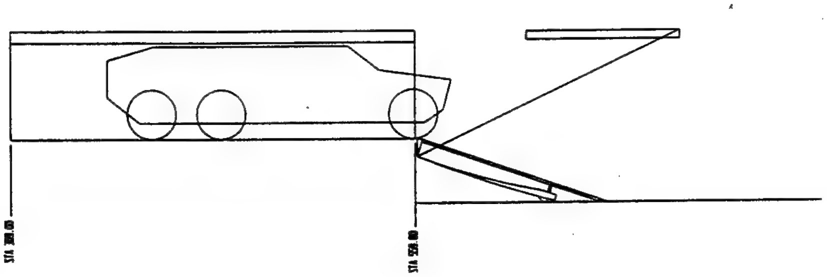
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.67 BUMP
AXLE 3: 3.95 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.7



WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.44 BUMP
AXLE 3: 10.44 DROOP
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 1.1

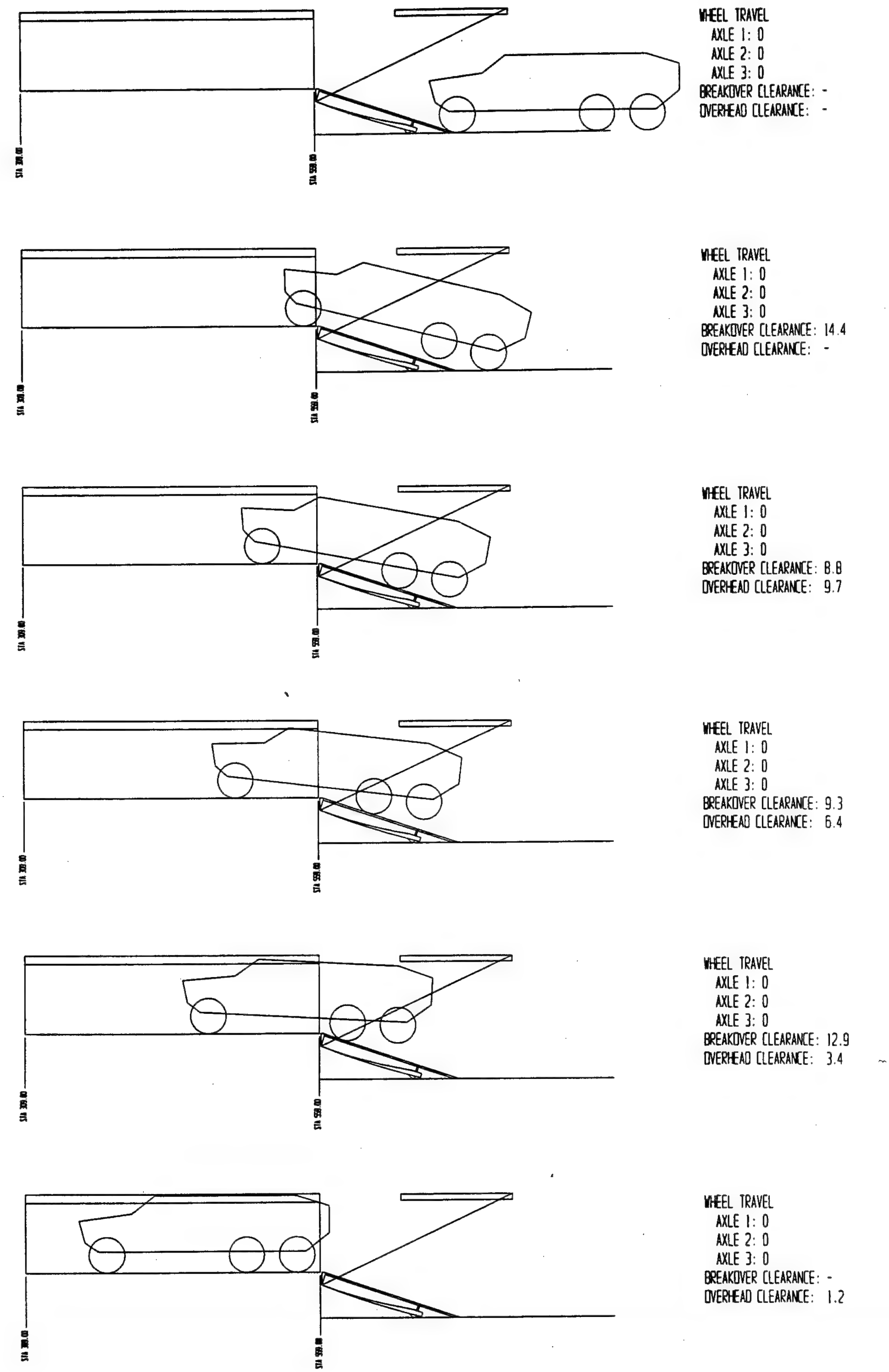


WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.53 BUMP
AXLE 3: 8.58 DROOP
BREAKOVER CLEARANCE: -1.4
OVERHEAD CLEARANCE: 2.1

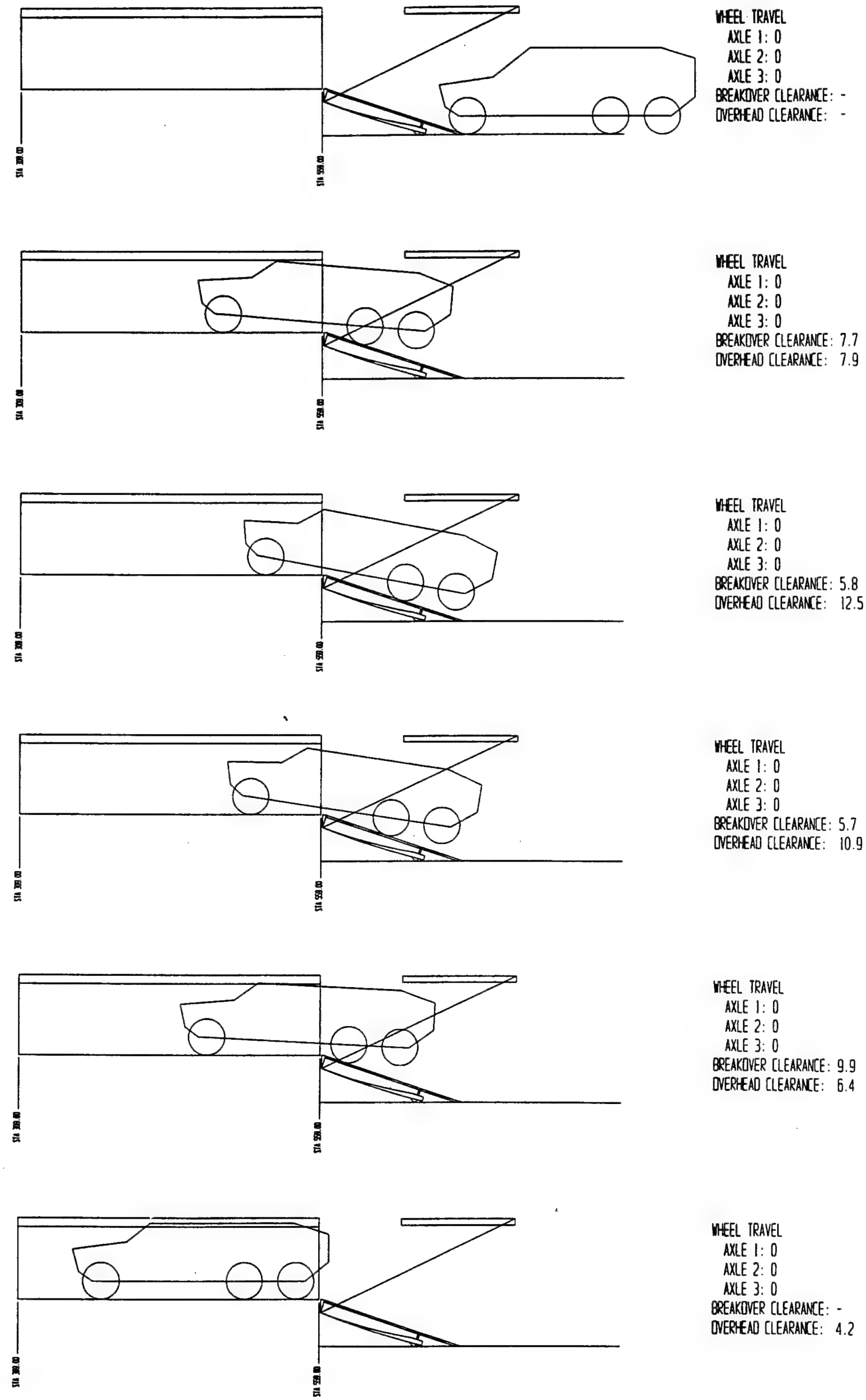


WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 9.2

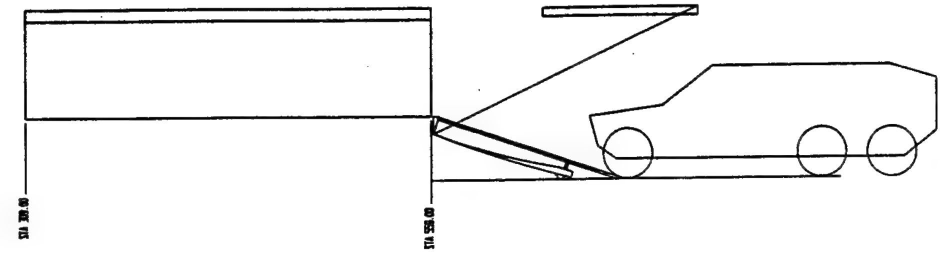
SEQUENCE 9: NOTIONAL RSTA-V AT 18 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN FORWARD.



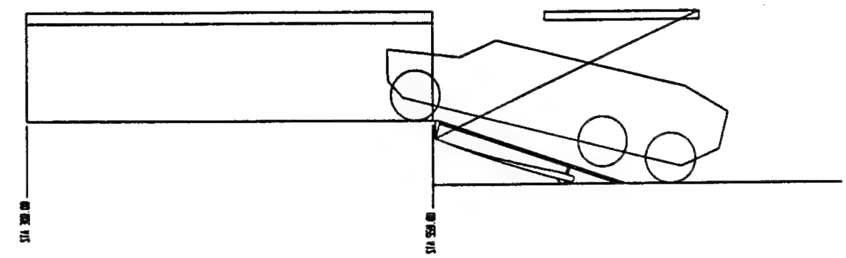
SEQUENCE 10: NOTIONAL RSTA-V AT 15 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN FORWARD.



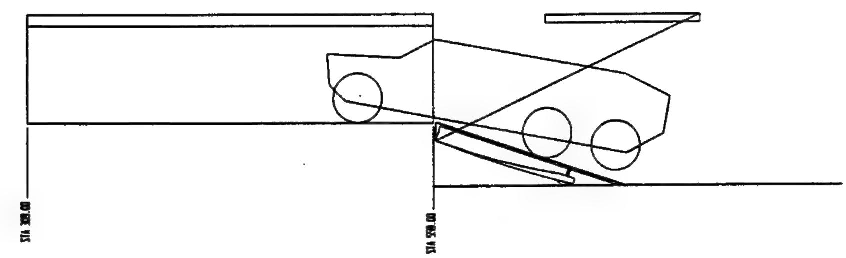
SEQUENCE 11: NOTIONAL RS/A-V AT 12 INCH RIDE HEIGHT
WITH NO WHEEL TRAVEL ROLLING IN FORWARD.



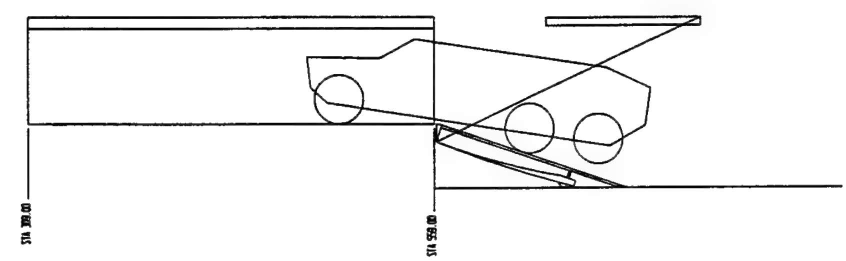
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



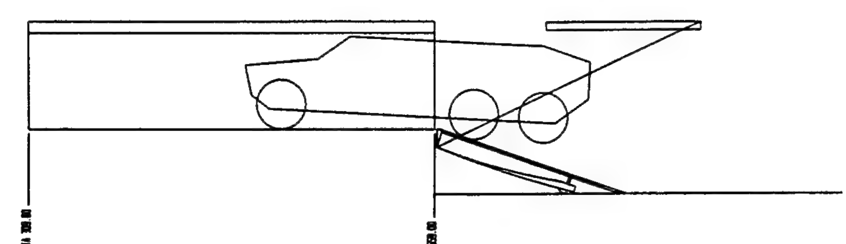
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 8.4
OVERHEAD CLEARANCE: -



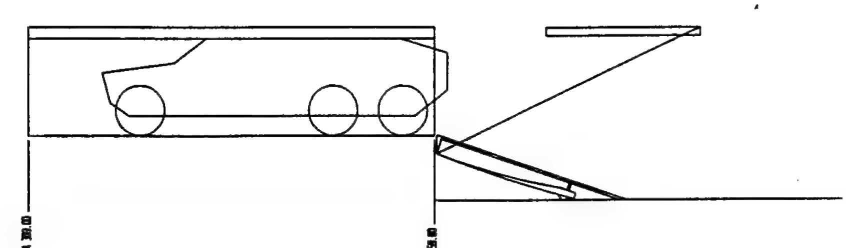
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 2.8
OVERHEAD CLEARANCE: 15.4



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 2.7
OVERHEAD CLEARANCE: 13.8

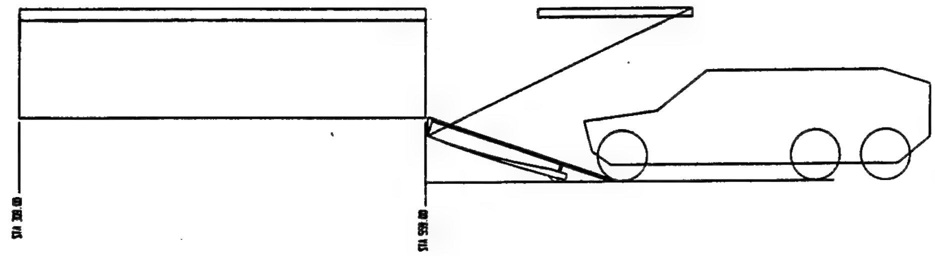


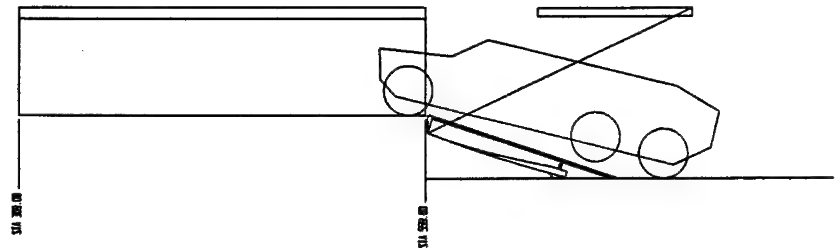
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: 6.9
OVERHEAD CLEARANCE: 9.4

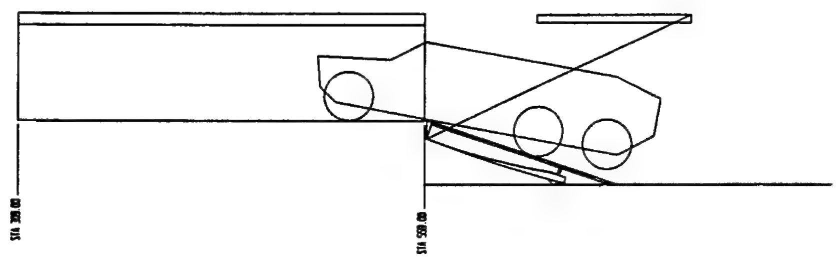


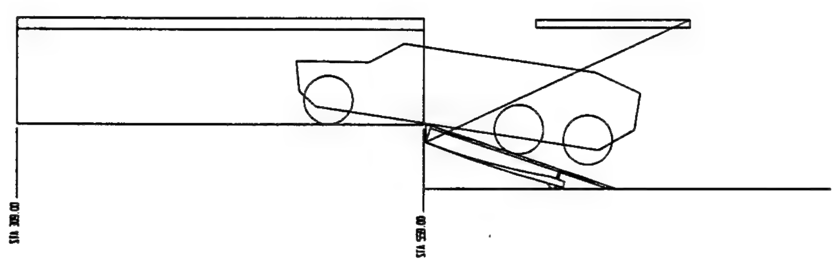
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 7.2

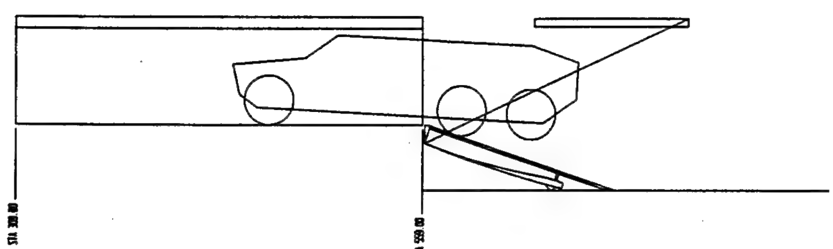
SEQUENCE 12: NOTIONAL RSTA-V AT 10 INCH RIDE HEIGHT WITH NO WHEEL TRAVEL ROLLING IN FORWARD.

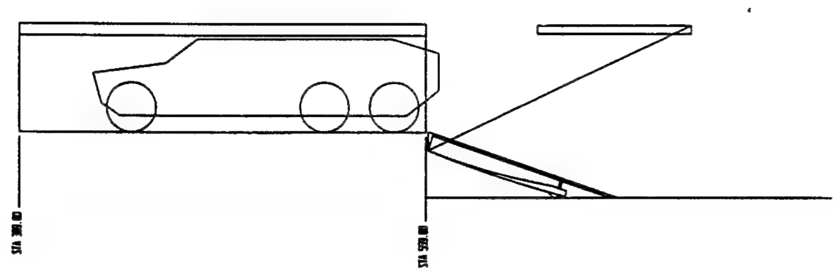


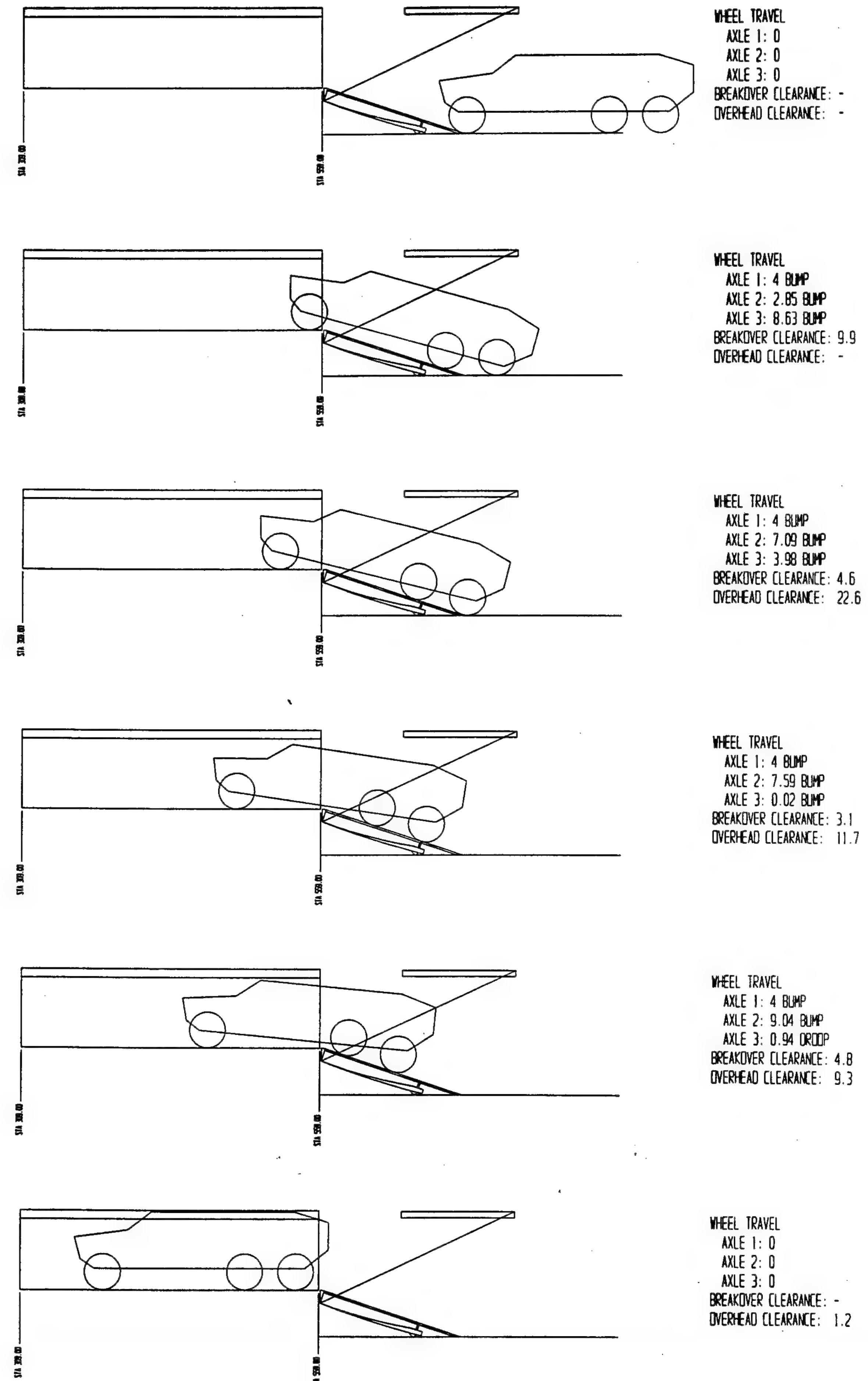




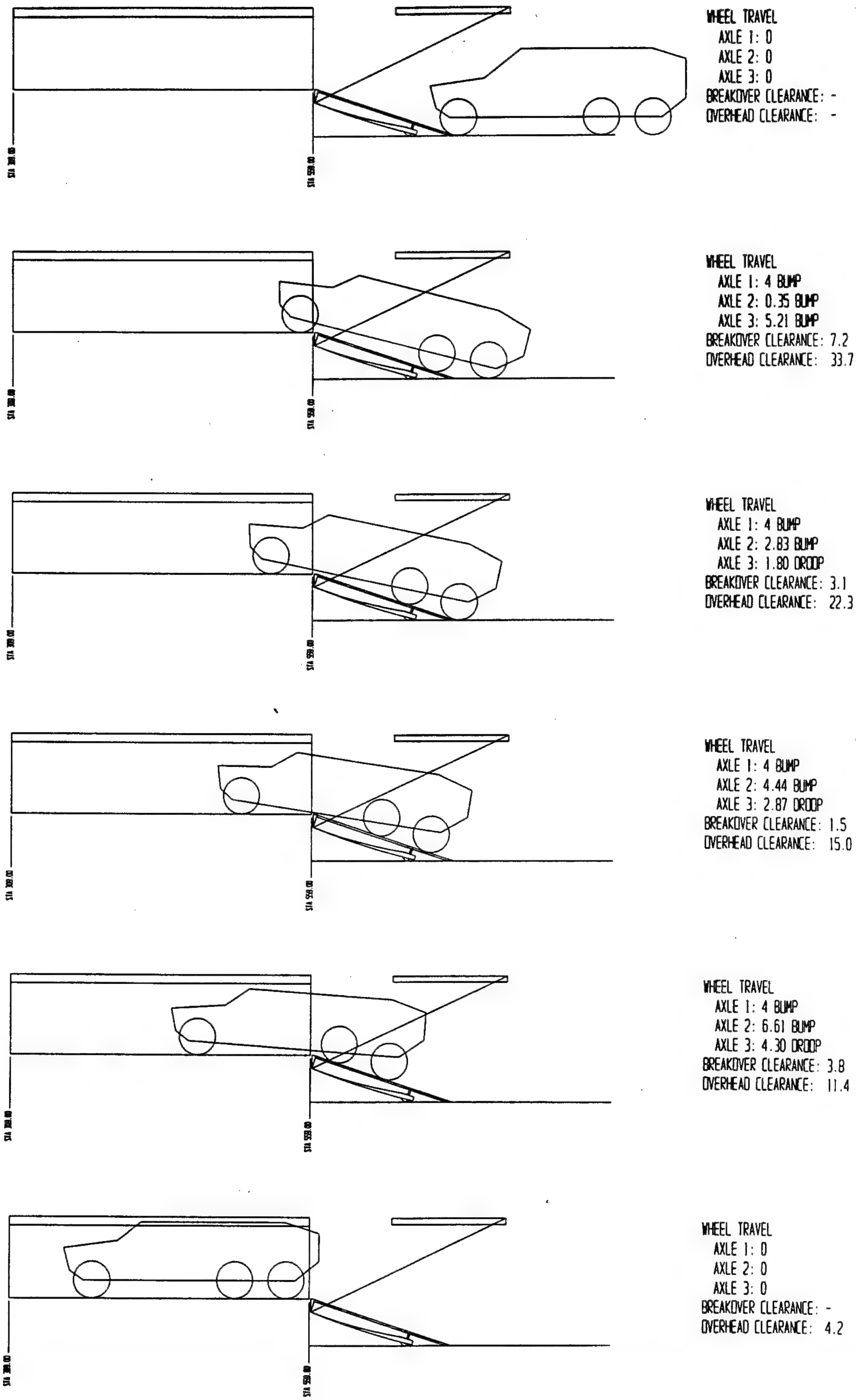




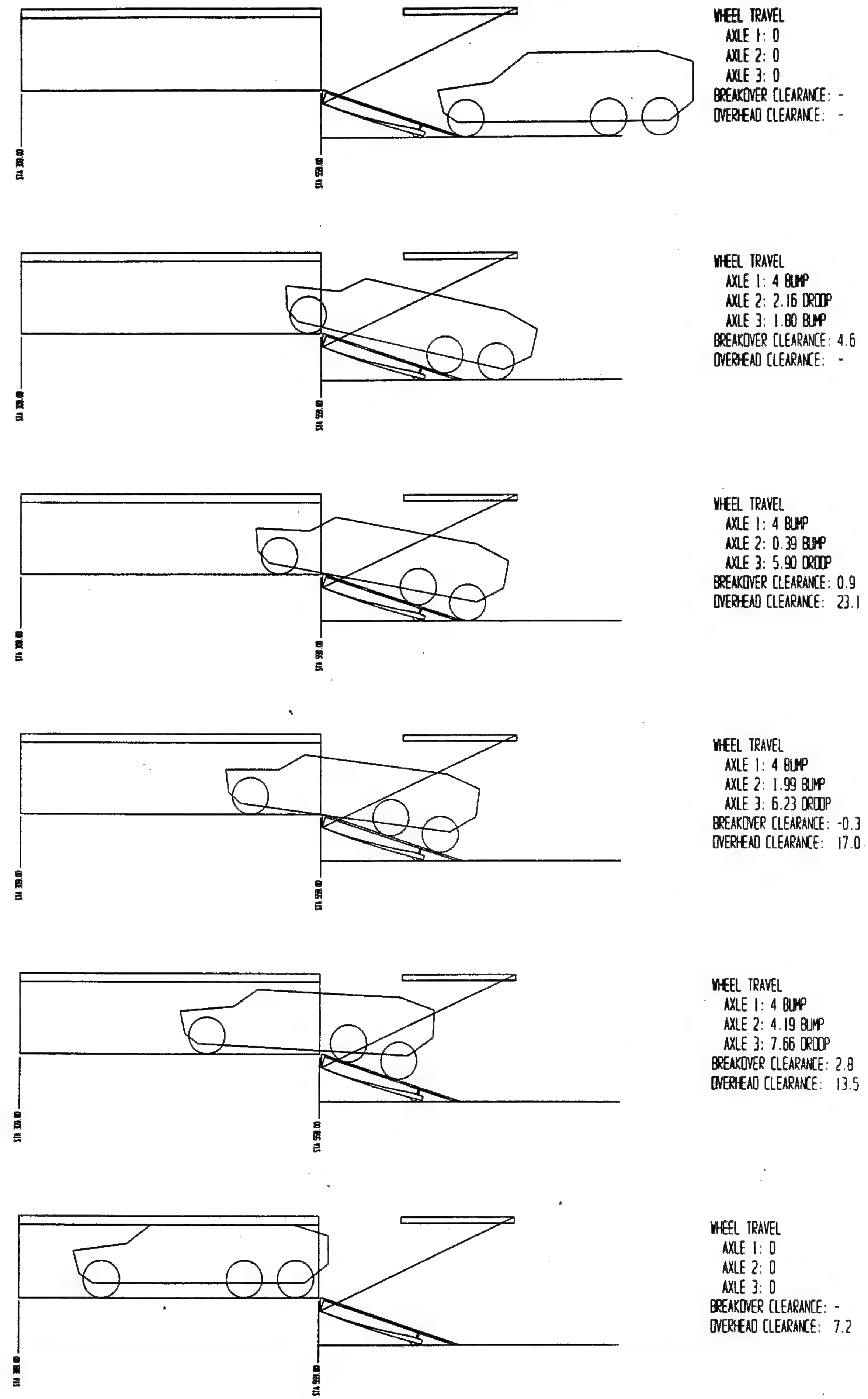




SEQUENCE 13: NOTIONAL RSTA-V AT 18 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN FORWARD.

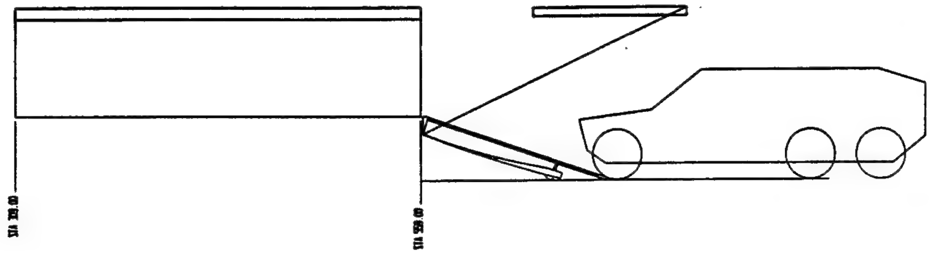


SEQUENCE 14: NOTIONAL RS,A-V AT 15 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN FORWARD.

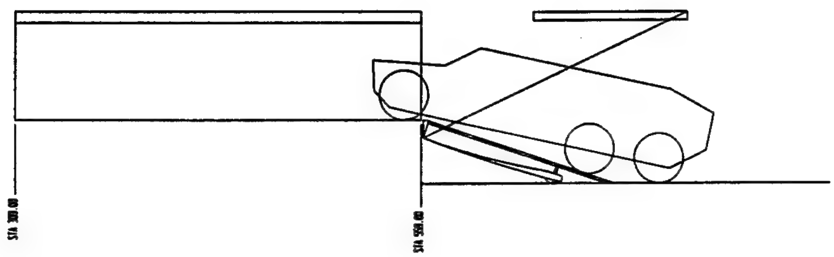


SEQUENCE 15: NOTIONAL RSTA-V AT 12 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN FORWARD.

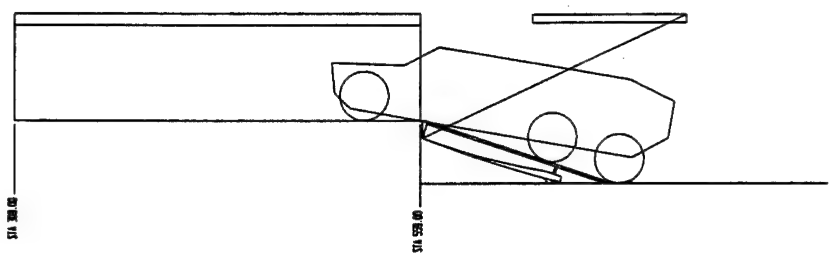
SEQUENCE 16: NOTIONAL RSTA-V AT 10 INCH RIDE HEIGHT WITH WHEEL TRAVEL ROLLING IN FORWARD.



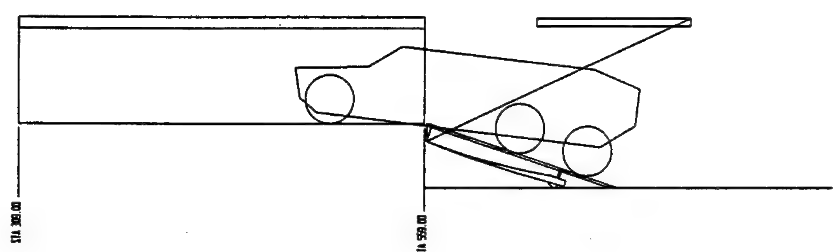
WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: -



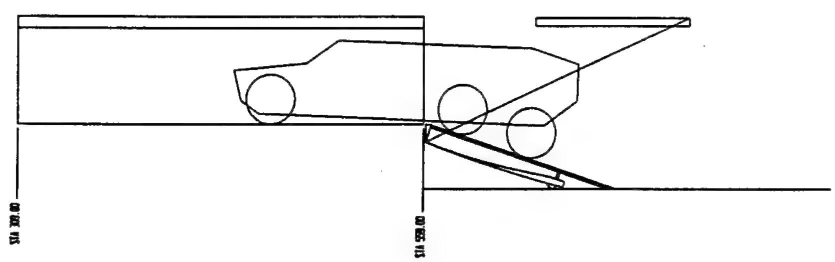
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 3.84 DROOP
AXLE 3: 0.47 BUMP
BREAKOVER CLEARANCE: 2.9
OVERHEAD CLEARANCE: -



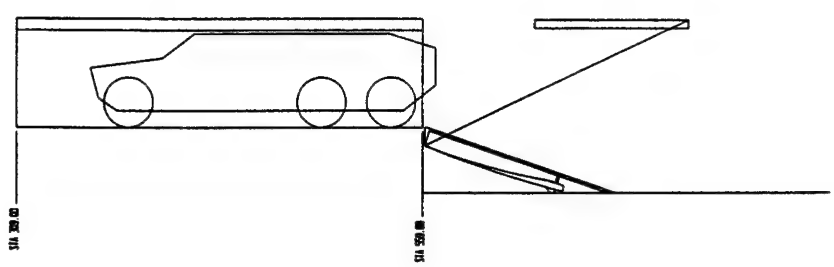
WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 1.23 BUMP
AXLE 3: 7.26 DROOP
BREAKOVER CLEARANCE: -0.6
OVERHEAD CLEARANCE: 23.9



WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 0.37 BUMP
AXLE 3: 8.47 DROOP
BREAKOVER CLEARANCE: -1.4
OVERHEAD CLEARANCE: 18.4



WHEEL TRAVEL
AXLE 1: 4 BUMP
AXLE 2: 2.57 BUMP
AXLE 3: 9.91 DROOP
BREAKOVER CLEARANCE: 2.1
OVERHEAD CLEARANCE: 14.9



WHEEL TRAVEL
AXLE 1: 0
AXLE 2: 0
AXLE 3: 0
BREAKOVER CLEARANCE: -
OVERHEAD CLEARANCE: 9.2

DIMENSIONAL FIGURES OF A NOTIONAL RSTA-V

Addendum c.

FIGURE 1: RSTA-V MODEL FRAME, AXLES AND WHEELS

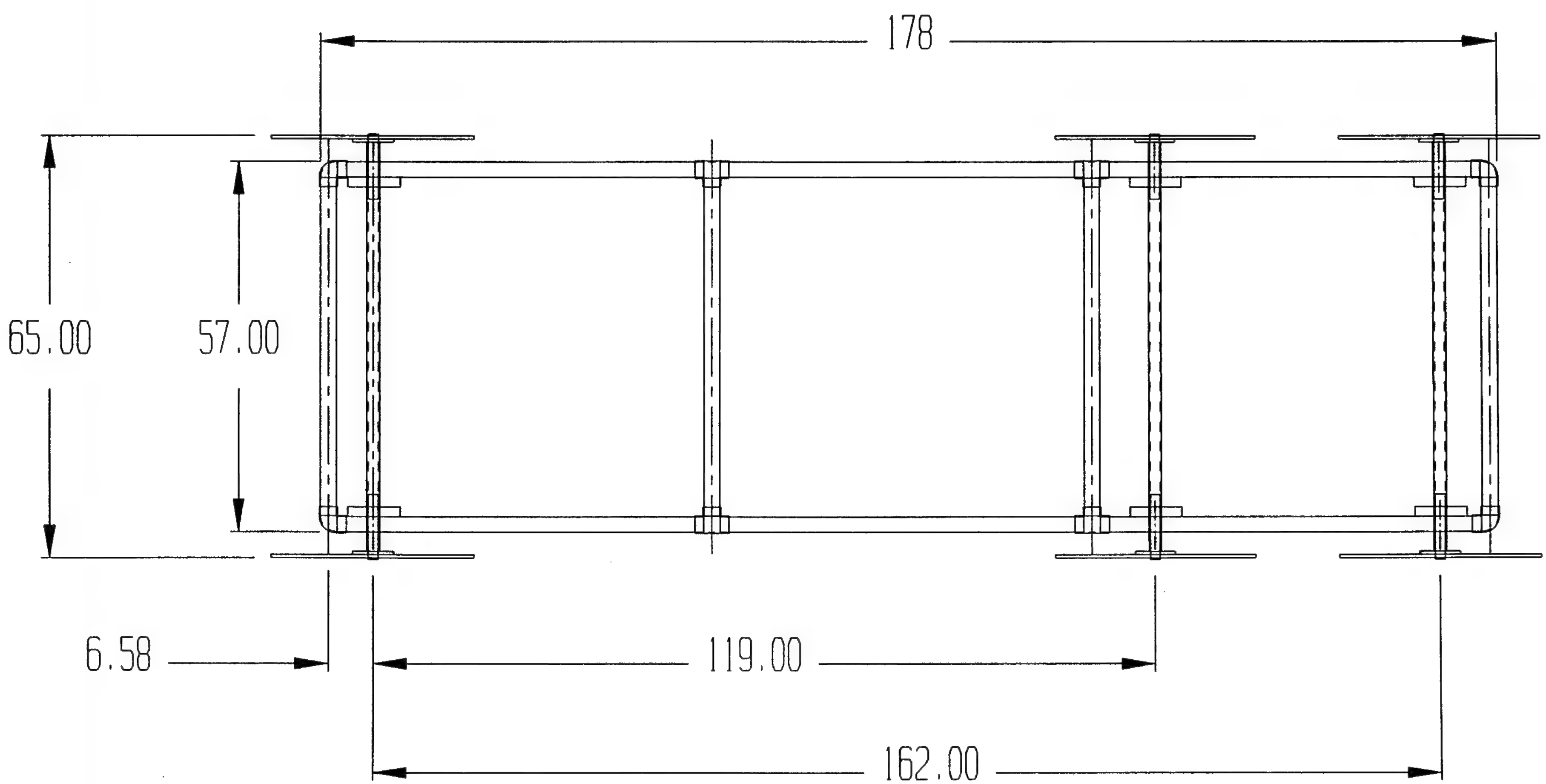


FIGURE 2: VEHICLE SIDE PROFILE

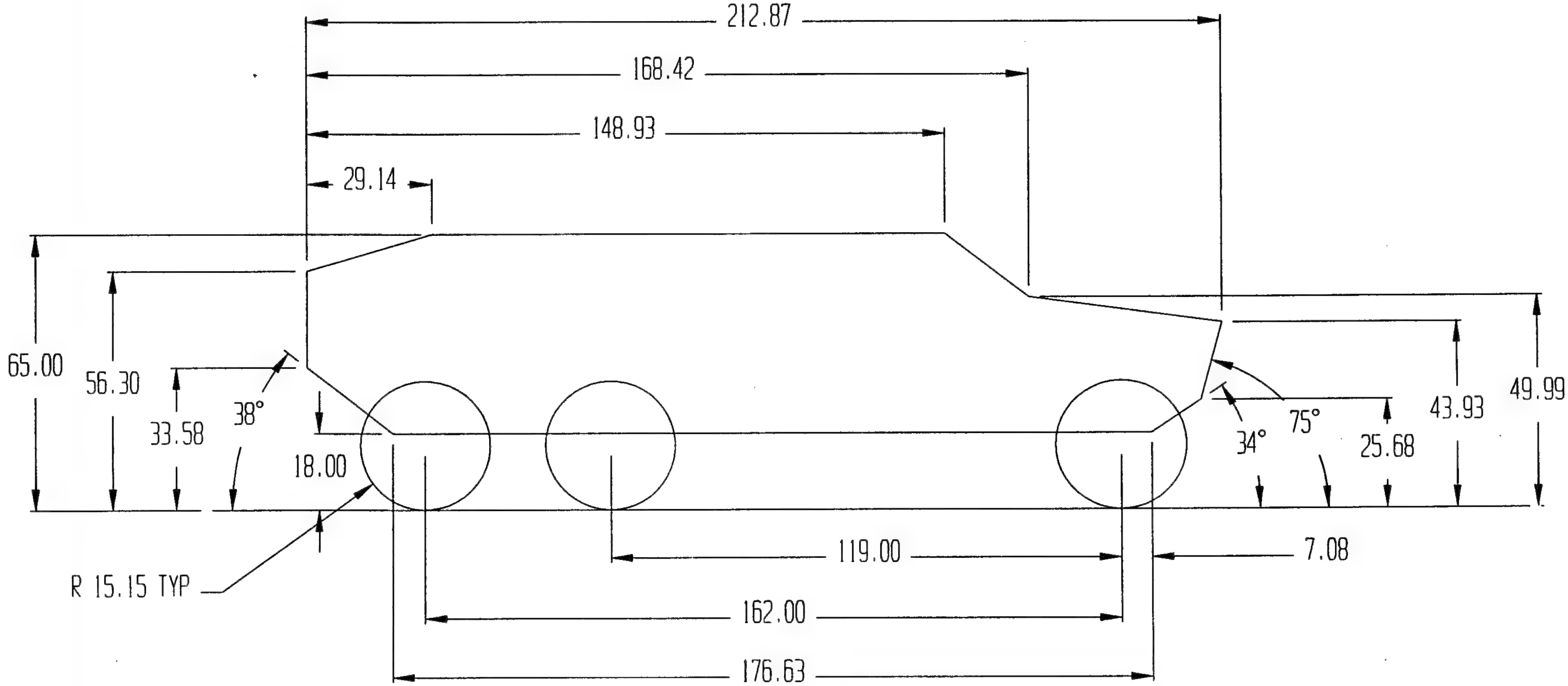


FIGURE 3: FRONT BODY PROFILE

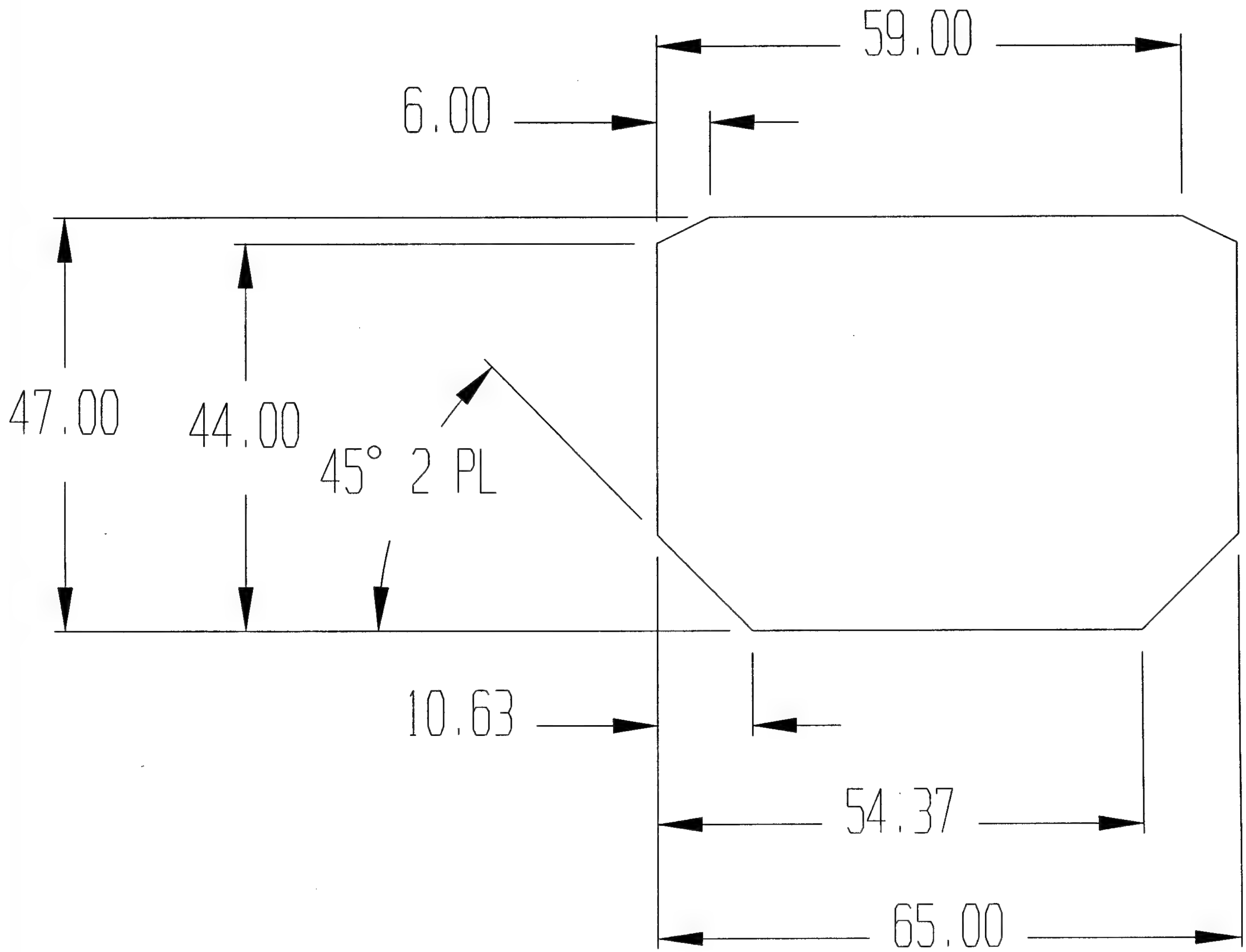


FIGURE 4: THE LIMITING CASE DEFINING THE VEHICLE ENVELOPE

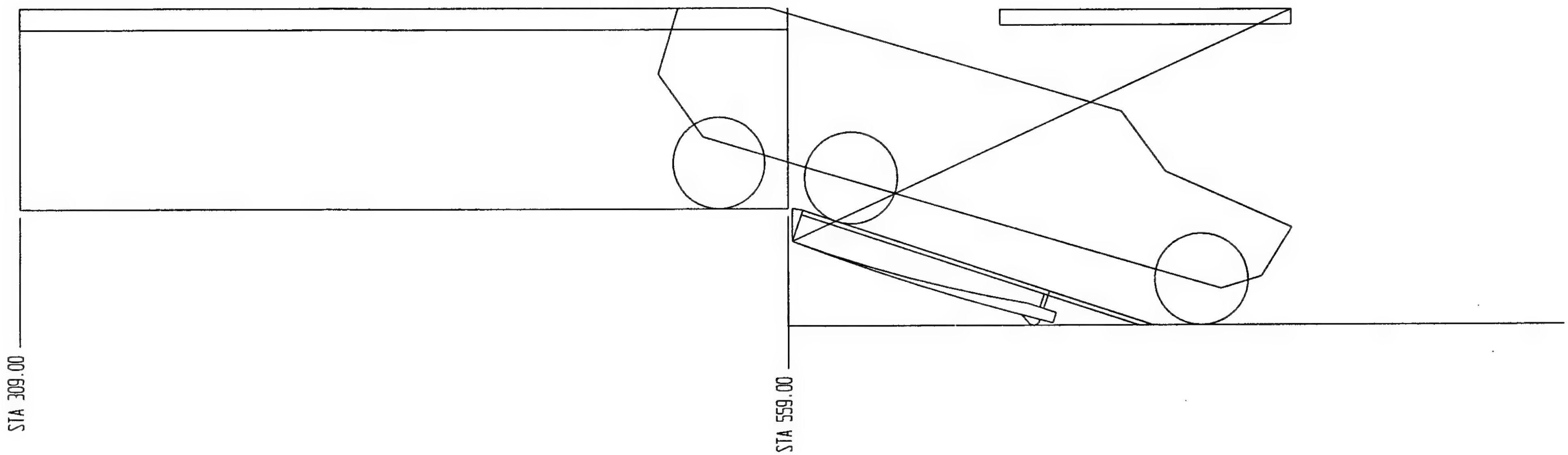
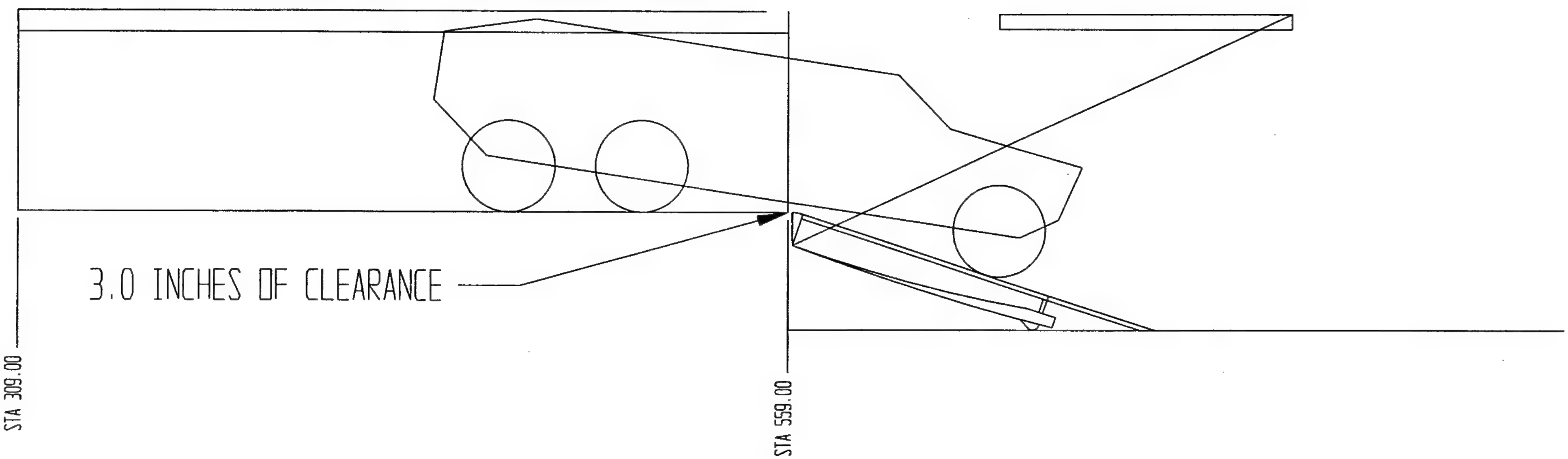


FIGURE 5: 18" RIDE HEIGHT WITH WHEEL TRAVEL



Appendix F

V-22 Aircraft Fitcheck #2 (Aircraft Issues Report)

9 October 1998

From: Mr. Larry Smith, V-22 ITT
Mr. Nick Runowich, NAWCAD 4.3.5

To: LCOL J. Rudzis, V-22 GFTD
CDR Schwartzenburg, V-22 Class Desk
Mr. Joe Carbonaro, V-22 Deputy GFTD
Mr. Roger Marr, V-22 CFTD
Mr. Mike Kumpel, V-22 Planning

Cc: CAPT Thompson, NRWATD Commanding Officer
Mr. Dave St. Jean, V-22 Deputy Class Desk
Mr. Larry Thomas, NAWCAD 4.11.5
Ms. Jackie White, NAWCAD 4.11.5.1
Mr. J. Bradel, NSWC Carderock
Mr. J. Cerulli, MAPC

Subj: Trip Report: MV-22B Aircraft 10 Fit Check with HTTV

Ref: (a) SD-572-1, Detailed Specification for V-22 EMD, Revision C, dated 13 Sept 95 (modified 12 Dec 95).

Encl: (1) Attendence List

INTRODUCTION

1. Background. Naval Surface Warfare Center, Carderock Division (NSWCCD) is developing a special operations vehicle that is internally transportable by the V-22. NSWCCD coordinated with V-22 Class Desk and Multiservice Operational Test Team (MOTT) for test time to conduct a fit check of the Helicopter Transportable Tactical Vehicle (HTTV) in the MV-22B. The fit check was conducted 24 September 1998 on A/C 10 during OT-IID at MCAS New River. The fit check was conducted in 2.5 hours.

2. Description. The HTTV is a prototype light tactical vehicle that was designed to be loaded into the MV-22B. The purpose of this test was to evaluate the compatibility of the HTTV with the V-22. The HTTV test weight was approximately 5000 lbs and width was 62 inches. The HTTV was powered at all four wheels by a General Motors 6.5L turbo diesel and 4L80-E automatic transmission. The HTTV tires extended approximately 1 inch past the vehicle body using the standard rims. HTTV personnel used a set of modified rims preventing the tires from extending past the vehicle body. Table 1 is a dimensional comparison between the HTTV and the V-22 Cargo Compartment.

Table 1:

HTTV / V-22 Specifications

Dimensions	HTTV	V-22 Cargo Compartment
Length (inches)	200 (incl winch)	250
Width (inches)	62	68 (ramp width: 65 5/8)
Height (inches)	61.75 (min)	66
Wheel Base (inches)	120	114.5 (ramp + flipper length)
Weight (lbs) (Empty/GW)	4700/6700	n/a

3. Method. This evaluation was conducted by driving the HTTV onto the aircraft forwards using a crew chief to direct the vehicle and two additional crew chiefs to monitor the clearances between the vehicle and the aircraft. Once the vehicle was loaded onto the aircraft, measurements and pictures were taken to document clearances. Then, the vehicle was off loaded and this process was repeated with the vehicle loaded backwards. The vehicle was loaded and unloaded slowly and cautiously to prevent any potential for aircraft damage. These evolutions were not timed because the quickness of the operation was beyond the scope of this evaluation.

RESULTS AND EVALUATION

4. Ramp Opening. The HTTV was loaded onto V-22 A/C 10 during day, dry conditions. The aircraft fuselage deck angle was zero degrees and the ramp angle was 20 degrees. The ramp extenders were installed such that the outboard edge of the ramp extenders lined up with the outboard edge of the ramp floor. The ramp extenders were 28.5 inches long and 15 inches wide. The ramp opening was 65 5/8 inches and the vehicle width was 62 inches using the modified rims. The break over clearance was dependent on suspension height and vehicle gross weight. The vehicle suspension was measured positioned on a level surface without a driver and was adjustable approximately 3 ¾ inches from a ground clearance of 8 inches to 11 ¾ inches. The HTTV was loaded once forwards and once backwards. The suspension was adjusted to full up for maximum break over clearance. The minimum clearances between the aircraft structure and the vehicle occurred at the ramp opening structure. The minimum lateral clearance was < ½ inch between the vehicle and airframe (ramp seal structure). The maximum break over clearance was 2 inches between ramp tunnel and vehicle under carriage. The HTTV was loaded but required constant attention from all three crew chiefs and the driver. The vehicle was stopped many times to ensure adequate clearances and to measure clearances. Given unlimited time and three crew chiefs plus a driver, the HTTV was loaded and unloaded without contacting any aircraft structure. Loading or unloading the HTTV on/off the V-22 with any sense of urgency, foul weather conditions, or at night using NVGs will potentially result in the HTTV contacting and damaging primary aircraft structure. The vehicle suspension will compress as the mission load weight increases resulting in reduced break over clearances. Recommend NSWCCD review their vehicle design to ensure the break over clearance at maximum GW with minimum and maximum suspension height is compatible with the V-22 ramp angle of 20 degrees. Recommend providing a ramp opening that is at least as wide as the cargo envelope. The ramp opening is currently being investigated for increasing the opening width.

5. Latching Mechanism/Buffer Boards. All aircraft troop seats except for the first two on the right side were installed for the vehicle loading. The buffer boards latching pins were rotated 90 degrees from a down position to the handle pointing outboard (could not rotate inboard due to

an interference with the troop seats). With the latching pin handles pointing outboard, the right aft buffer board was rotated up and pushed outboard. The latching pins were rotated down into the vertical position for latching. None of the latching pins latched. The buffer boards were moved back and forth and up and down and the latching pins rotated back and forth in an attempt to set the pin. None of the latching pins latched. An attempt to latch the left aft and right aft buffer boards on A/C 9 was also unsuccessful. A/C 9 only had 2 troop seats installed on the right side. None of the latching pins latched. The buffer boards were not deployed for the vehicle loading on A/C 10 due to the latching pins not latching. Loading wheeled vehicles and cargo without deploying the buffer boards will potentially result in damage to the troop seats and/or the airframe. Recommend investigating further the buffer board latching pins to determine the cause of lack of latching. However, the buffer board latching mechanism design has been changed and will be evaluated during the cargo handling system mock-up on A/C 2.

6. Blocked Troop Seats/Buffer Boards. The HTTV was loaded in the forward direction and located between STA 327 and STA 516. A life raft was positioned and secured to the LH avionics bay aft bulkhead STA 299. No cargo straps were installed to restrain the vehicle. An attempt was made to reach all of the buffer board latching pins to simulate stowing the buffer board allowing access to troop seats. On the forward, right side 3 of 7 latch pins were within reach; forward, left side 1 of 7 latch pins were within reach; aft, right and left side 6 of 7 latch pins were within reach. The pin between the forward and aft buffer board could not be reached on either side. The troop seats will not fold down with the buffer boards deployed. All seven latch pins and the pin that slides between buffer boards need retracted to stow the buffer boards which will allow access to a troop seat. A typical mission will require up to one crew chief seat and four troop seats for HTTV crew. With the buffer boards deployed and the HTTV loaded on the aircraft, the crew will not be able to stow the buffer boards to gain access to any troop seats for transit. Recommend providing the capability of gaining access to the crew chief seat and the last two troop seats on the left and right sides of the aircraft. However, the buffer board latching mechanism design has been changed and will be evaluated during the cargo handling system mock-up on A/C 2.

7. Vehicle Alignment. The ramp opening was 65 5/8 inches wide. The vehicle was 62 inches wide. Aligning the vehicle with the ramp opening for loading in both the forward and backward directions were difficult requiring two to three attempts to achieve an acceptable position for loading. The precision and time required to load a 62 inch wide vehicle into a 65 5/8 inch opening is not mission suitable. Adverse weather conditions will make this task more difficult. Recommend investigating a system to align the vehicle as it enters the cabin (similar to a car wash system). The ramp width has been previously squawked and is currently being redesigned. The ramp opening redesign will not be installed for the cargo handling system mock-up on A/C 2.

8. Cargo Envelope. The vehicle height was measured as 61 ¾ inches minimum and 65 ½ inches maximum. The V-22 cargo envelope is 68 inches wide. The height of the cargo envelope is 66.2 inches from LBL 20.77 to RBL 20.77. From left and right BL 20.77 to left and right BL 34 the height tapers to 59.18 inches. The HTTV, if the centerline of the vehicle is lined up on the centerline of the aircraft, will not fit inside the V-22 cargo envelope. However, the HTTV will fit inside A/C 10 as configured for this test. Recommend NSWCCD vehicle designs not exceed the V-22 cargo envelope to ensure compatibility in the future. Recommend V-22 Cargo Handling IPT assess the V-22 cargo compartment for growth above WL 140.

9. Tie Downs. The vehicle gross weight was approximately 5000 lbs. Restraining the HTTV inside the V-22 was analyzed with the vehicle loaded in the forward direction located between between STA 330 and STA 519. The cargo restraint criteria as specified in reference (a) are: 16 g longitudinal (fwd), 5 g up, 16 g down, 10 g lateral, and 5 g aft. The dynamic criteria can not be used in the longitudinal direction because the vehicle is within ½ inch of the crew chief seat and the dynamic criteria can not be used in the lateral direction because of the minimal clearances between the vehicle and the aircraft frames. Therefore, the following analysis to determine the number of straps required to restrain the HTTV inside the V-22 was evaluated for 16 g forward (no attenuator stroke), 5 g up (no attenuator stroke), 16 g down (no attenuator stroke), 10 g lateral (no attenuator stroke), and 5 g aft (no attenuator stroke). In the forward direction, the static restraint required was 5,000 lbs x 16 g = 80,000 lbs. The load attenuators begin to stroke at 4800 lbs; therefore each strap was limited to 4800 lbs. 80,000 lbs / (4800 lbs x cos 45° x cos 15°) = 24.4 or twenty-five straps oriented <= 45° angle from the deck and <= 15° laterally from the vehicle attach point are required to restrain the HTTV in the forward direction. The aft direction tie down criteria is 5g, requiring eight straps. The lateral direction tie down criteria is 10g requiring eleven straps for left restraint and eleven straps for right restraint. No additional straps are required to restrain the vehicle in the vertical direction. The total number of straps required to restrain the HTTV in accordance with reference (a) is 55 straps. Only the last two rows of cabin floor tie down rings and the first row of cabin floor tie down rings were available for restraining the vehicle in all directions. The vehicle does not have 55 tie down locations, the aircraft does not have 55 tie down fittings available with the vehicle loaded, and the V-22 does not have 55 cargo tie down straps. The HTTV can not be restrained to the requirements of reference (a) due to lack of aircraft tie down rings, lack of tie down straps, and lack of vehicle tie down attach points. Transporting the HTTV in the V-22 can not be performed given the restraint requirements of reference (a). Recommend increasing the V-22 tie down ring ratings, increasing the number of V-22 tie down rings, investigating alternated tie down schemes, investigating reducing the length, width, and weight of the HTTV, lowering the cargo tie down requirements of reference (a), and/or increase the number of cargo straps per ship set. Tie down configurations will be evaluated during the cargo handling system mock-up on A/C 2.

10. Center of Gravity. An analysis is being conducted to determine the center of gravity position as fuel is burned and/or loaded with the HTTV and crew loaded in the MV-22B. The results of this analysis will be addressed in a separate correspondence.

RECOMMENDATIONS

11. Recommend NSWCCD review their vehicle design to ensure the break over clearance at maximum GW with minimum and maximum suspension height is compatible with the V-22 ramp angle of 20 degrees. Recommend providing a ramp opening that is at least as wide as the cargo envelope (paragraph 4).

12. Recommend investigating further the buffer board latching pins to determine the cause of lack of latching. However, the buffer board latching mechanism design has been changed and will be evaluated during the cargo handling system mock-up on A/C 2 (paragraph 5).

13. Recommend providing the capability of gaining access to the crew chief seat and the last two troop seats on the left and right sides of the aircraft. However, the buffer board latching mechanism design has been changed and will be evaluated during the cargo handling system mock-up on A/C 2 (paragraph 6).

14. Recommend investigating a system to align the vehicle as it enters the cabin (similar to a car wash system). The ramp width has been previously squawked and is currently being redesigned. The ramp opening redesign will not be installed for the cargo handling system mock-up on A/C 2 (paragraph 7).

15. Recommend NSWCCD vehicle designs not exceed the V-22 cargo envelope to ensure compatibility in the future. Recommend V-22 Cargo Handling IPT assess the V-22 cargo compartment for growth above WL 140 (paragraph 8).

16. Recommend increasing the V-22 tie down ring ratings, increasing the number of V-22 tie down rings, investigating alternated tie down schemes, investigating reducing the length, width, and weight of the HTTV, lowering the cargo tie down requirements of reference (a), and/or increase the number of cargo straps per ship set (paragraph 9). Tie down configurations will be evaluated during the cargo handling system mock-up on A/C 2.

Sincerely,

Larry Smith Nick Runowich

Appendix G

V-22 Aircraft Fitcheck #2 (Ground Vehicle Issues Report)

V-22 Fit Test Report

Background

The Marine Corps Program Office at the Naval Surface Warfare Center – Carderock Division (NSWCCD) is continuing its development of advanced light tactical vehicles to meet future warfare needs. One of the products of this effort is the Helo Transportable Tactical Vehicle (HTTV). The HTTV is a light tactical vehicle that was designed to be loaded into the V-22.

Test Authority

Maritime Applied Physics Corporation (MAPC), acting as an agent for NSWCCD, has been executing the maintenance, transportation, demonstration oversight, and vehicle development for the Helicopter Transportable Tactical Vehicle (HTTV). MAPC and the V-22 Flight Test engineering staff conducted the test on Aircraft #10 located at New River, NC on September 24th. MAPC served as the Test Coordinator for the fit-check.

September Fit Tests

The Marine Corps performed one days of testing to verify that the HTTV can be loaded and secured in the V-22. This testing and subsuquint testing will help define some of the logistics problems of loading, unloading and restraining the HTTV in the cargo envelope of the V-22. Data accumulated during the tests will be used in the evaluation of the compatibility between the two vehicles, to identify interference problems, and to design a suitable restraining system.

Test Article Modifications

The HTTV was slightly modified for this test to stay within the constraints of the V-22 cargo envelope (an HTTV specification sheet can be found in appendix A). A new set of wheels and tires were installed to decrease the overall width of the vehicle. A new set of front spring retaining caps were made, and the front shock adjustment was adjusted to its full up position, decreasing the overall length of the shock/spring assembly. The adjustable connecting rod between the rear rocker arms and the A-arms were replaced with a new set that decreased the length of the connecting rod two inches, therefore lowering the rear of the vehicle. These modifications brought the overall vehicle height, when in the lowered position, down to sixty

inches from sixty-seven inches. These were necessary for the HTTV to fit inside of the V-22 cargo envelope, however some of the vehicle preformance characteristics changed as a result. The main characteristic that changed was the roll-over potential, which increased due to a narrower track width (a detailed summary of the vehicles center of gravity characteristics is detailed in appendix D-H). No testing was preformed to quantify the effects of the mechanical changes upon the vehicle performance.

Tasks

The scheduled tasks for the test included:

1). Verify that the V-22 and HTTV are properly configured for safe loading of the HTTV.

2). Install alignment guides and drive the vehicle forward into the aircraft.

3). Once the vehicle is loaded, take measurements to determine the vehicles attitude and position relative to the airframe.

4). Remove the HTTV from the V-22 and repeat process with the vehicle backed into the aircraft.

5). Close the rear cargo hatch and take clearance measurements.

6). Again remove the HTTV, install the restraining harness and take clearance measurements.

This whole evolution was estimated to take three hours. (A detailed description of the testing procedure can be found in attachment B.)

Schedule/ Results

The testing time was restricted to only about one and a half-hours due to problems with the V-22, which required the maintenance crew to work on the aircraft. Due to good weather conditions and tireless support from the V-22 flight test crew, however a fair amount of valuable test data was obtained in the short time period given.

The V-22 cargo deck was at zero degrees and the ramp angle was at twenty degrees relative to the horizontal plane. The first task was to load the vehicle in the forward facing direction. This was accomplished in approximately twenty minutes. The HTTV was determined to have insufficient clearance when in the lowered position to clear the twenty degree break over angle of the ramp; therefore the HTTV was loaded with the ride height adjustment set in the full

up position. This enabled the HTTV to clear the brake over angle. However the ride height must be lowered to its lowest position in small increments as the vehicle enters the cargo area in order not to violate the cargo envelope constraints (a drawing of the vehicles path while entering the V-22 can be found in appendix I). While entering the cargo envelope of the V-22 the HTTV, at its closest point, still had two inches of clearance between its belly pan and the ramp hinge point. (This distance can change by up to five inches or more depending on the load carried by the vehicle). There is a tight tolerance between the V-22 cargo hatch door gasket opening (65") and the HTTV width (62"). Also the alignment is crucial to ensure that the vehicle remains within the constraints of the door gasket in addition to the cargo envelope as it enters the V-22. Tight tolerances and concern for the safety of the aircraft are the reason for the extensive amount of time that it took to align and load the vehicle. The HTTV had 2.125" of clearance between the vehicle and the rear cargo hatch door gasket on the passenger side. There was only .75" of clearance between the vehicle and the rear cargo hatch door gasket on the driver side. Once the vehicle was in the cargo area, measurements were taken to determine the vehicles attitude and it's relationship to the airframe. Measurements were made from the vehicle to the various locations around the interior of the V-22 (a complete list of all measurements can be found in appendix C). It was found that there was a clearance problem between the buffer boards (a retractable device that is attached to the airframe to limit the path of cargo to only the cargo envelope) and the vehicle. The buffer boards, if in the raised position while the vehicle is being loaded, couldn't be lowered once the vehicle had entered the cargo area. This eliminated the possibility of using the troop seating, which would be desirable, while transporting the HTTV. The V-22 flight test crew and Boeing are investigating the problem. The vehicle was then backed out of the V-22. This took less time than pulling the HTTV in since this was the second time through the door and the vehicle was already aligned with the opening.

The second task was to back the vehicle into the V-22. This was performed in approximately ten minutes, but it still took a considerable amount of effort to align the vehicle with the door opening, and the vehicle again needed to be lowered as it entered the cargo area. Once the vehicle was in the cargo area, measurements were again taken to determine the vehicles attitude and it's relationship to the airframe. The alignment of the HTTV after being backed into the V-22 was more precise on this attempt than when driven in the forward direction. This was due mainly to the fact that V-22 flight crew had a better understanding of the clearance

issues (a complete list of measurements can be found in appendix C). Three Marines sat in the vehicle during the second evaluation to determine whether or not the vehicle seating could be a suitable location for troops during transport. All three Marines reported that personnel could ride in the vehicle seating if needed. The vehicle was then driven partially out of the V-22 and measurements were taken between the HTTV belly pan and the V-22 ramp hinge point. There were two inches of clearance at its closest point. Then the vehicle was driven the rest of the way out of the V-22.

Future Changes

It was evident throughout both evolutions that this procedure might not be operationally feasible even in ideal conditions with this model airframe, due to the amount of time required to align the vehicle with the cargo opening. The cargo opening will be widened on future generations of the V-22 to the full sixty-eight inches of the cargo envelope width, which will simplify this process. Also, four troop seats would be available aft of the HTTV if the buffer boards were made to retract under those seats. The crew chief's seat would also be available if the buffer board was made to retract after vehicle loading. Although the buffer board system is a valuable asset in protecting the troop seating and the airframe from damage when loading palletized cargo, it is insufficient at protecting the aircraft from damage when loading large motorized vehicles such as the HTTV. The HTTV with its wheels set back from the corners of the vehicle can impact the seats and the airframe if the vehicle is slightly out of alignment, before the wheels ever reach the buffer boards. In addition the vehicle has sufficient mass and power to deform the buffer boards of the V-22. During this test there was not enough time to evaluate the unique restraining system developed by MAPC. Further evaluation of this system is needed. A system for aligning the HTTV in relationship to the V-22 would be helpful in decreasing the time and effort needed load and unload the vehicle.

Fit Test at Pax River

The vehicle was taken to Pax River on November 9,1998 for continued evaluation of the fit compatibility between the V-22 and HTTV. The evaluation was done on Aircraft #2, which was configured to resemble the next generation of the V-22. The door gasket had been widened to the full sixty-eight inches. The latching mechanism on the buffer boards had been modified to allow for easier engagement and disengagement from the up and locked position. A cargo roller

system had also been installed in the aircraft and was evaluated as a possible interface point for the vehicle guidance system. The tie-down ring arrangement on the cargo area floor had been slightly modified due to a reconfiguration of the cargo hook compartment. The HTTV used in this test had the same tires, rims and suspension as installed during the test at New River, NC. The HTTV used, however, did not have the same cargo volume or the water can rack and winch, which affected the overall length of the vehicle. The vehicle was aligned with the aircraft and guided in by the V-22 flight test crew in the forward facing direction and with the suspension all the way up. Due to the additional width clearance between the aircraft and the vehicle (3") it only took one minute to load the vehicle. This is considerably less time than it took on aircraft #10 at New River. The buffer board system was raised and lowered with the vehicle inside the aircraft. The operation of the buffer boards seemed much easier however there was still some resistance to locking. The roller tracks were .25" wider than the interior track width of the HTTV when in the raised position. The vehicle was then removed from the aircraft, turned around, and backed into the V-22. Once loaded, clearance measurements were recorded (see appendix D for a complete list of the recorded measurements).

The vehicle was then removed from the aircraft and the restraining harness was laid out on the floor. The harness was originally intended to be held down by ~ 50 cargo straps with load attenuators. Due to the redesign of the load attenuators, the length was increased to eighteen inches, which limited the placement of the straps to only the longer length tie-downs. In addition the localized floor loading that the attenuators would create when driven over by the vehicle far exceeds the maximum rating of the cargo floor (50 psi.). The load attenuation will have to be designed into the restraining harness itself. The harness was attached to the deck with thirteen of the fifty ratchet straps, two at each corner, two at the midpoint on each side, and one between the side midpoints. The system is fairly complex to attach to the V-22 cargo deck and takes a considerable amount of time to apply and correctly tension the ~50 straps required, however this system comes very close to meeting the sixteen g shock requirement in the longitudinal direction, ten g in the lateral direction. The vertical requirements five g (up) and sixteen g (down), and the five g aft requirements are all theoretically met when this harness is installed correctly.

Conclusion

The two fit checks evaluated the compatibility of the HTTV vehicles with the V-22 delivery aircraft. The following major conclusions were reached:

(1) Loading with the next generation V-22 door is fairly simple and rapid (approximately 1 min.)

(2) The loading process will be improved with the use of a guidance system

(3) Articulation of the suspension is required due to the decreased brake over angle of the HTTV when in the lowered position and inclination of the ramp.

(4) Use of the restraining harness is theoretically effective in securing the vehicle, at the design required g loads. Although additional work will have to be preformed to reduce the time required to secure the vehicle.

(5) Loading and unloading of large motorized vehicles such as the HTTV is predicted to be less than desirable (not rapid enough) during combat, at night, or in poor weather conditions.

HTTV SPECIFICATIONS

Length	With .50 cal. gun stowed	208 inches (4.87 meters)
	Without gun	199 inches (5.05 meters)
Width		62.5 inches (1.59 meters)
Minimum Height (variable)		60 inches (1.52 meters)
Wheel Base		119.28 inches (3.03 meters)
Track Width		50.5 inches (1.28 meters)
Approach Angle (w/o winch)		40 – 50 degrees (variable)
Departure Angle		29 – 35 degrees (variable)
Ground Clearance		5 – 9.5 inches (0.1-.24meters)
Tire Size		9.0 X 16 X 35 LT
Weight/Mass		
Curb Weight		4808 lbs. (2181 kg)
Payload		2435 lbs. (1104 kg)
GVW		7243 lbs. (3385 kg)
Typical Personnel Payload:		3 Crew = 555 lbs. (252 kg)
Personal gear & weapons		600 lbs. (272 kg.)
Heavy Weapon (M2 .50 cal.)		100 lbs. (45.4 kg.)
(12) Full cans ammunition (1200 rds.)		400 lbs. (181 kg.)
Camouflage netting		30 lbs. (13.5 kg.)
5 gal. water cans (4 ea.)		182 lbs. (82.5 kg.)
5 gal. Fuel cans (4 ea.)		140 lbs. (63.5 kg.)
Drivetrain		
Engine Type		GM Turbo Diesel
Displacement		395 cu. In. V8 (6.5 liter)
Max. Horsepower		190 hp (142 kW) @ 3400rpm
Max. Torque		385 lb-ft @ 1800rpm
Transmission		4 speed Hydramatic 4L80-E
Max. Transmission Input Torque		440 lb-ft
Differential Gear		New Process 242
Max. Differential Input Torque		885 lb-ft
Transmission Ratios (1st –4th)		2.482 / 1.482 / 1.000 / 0.750
Reverse Transmission Ratios		2.077
Low Range (1st-4th)		6.751 / 4.031 / 2.720 / 2.040
Low-Range Reverse		5.649
Performance		
Max. Speed		100+ mph (160+ kph)
Acceleration (0-60 mph/ 100kph)		11 seconds
Range		340 miles (550 km)
Max. Grade		60%
Side Slope		40%
Fording Depth(w/o kit)		30 inches (0.76 meters)

Appendix B

Detailed testing procedure

1) **Verify that the following requirements of the V-22 have been satisfied** Time:10min.

   a) Secure nose of V-22 to weights
   b) Install jacks at rear jack points
   c) Open V-22 cargo door
   d) Deploy ramp extensions
   e) Station #'s marked on decking (if not already marked, chalk markings will be installed)
   f) Cargo roller system is in the stowed position

2) **Verify that the following requirements of the HTTV have been met** Time: 5min.

   a) HTTV raise / lower system operational
   b) HTTV with dimension at tire bulge (> 65")
   c) HTTV CG clearly marked
      i) Lateral CG marked on hood and water can rack
      ii) Longitudinal CG marked on side panels and rear decking plates
      iii) Vertical CG marked on both the front grill and rear side panels
   d) Gun ring operational
   e) Fully loaded with cargo
      i) 50 cal. Rifle
      ii) Water cans
      iii) Alice packs
      iv) Ammo cans
      v) Camouflage netting
      vi) MRE's
      vii) Rear seat installed
   f) Cargo is adequately tied down
   g) Tire air pressure is 25psi.

3) **Install alignment guides in V-22** Time: 15min

a) Fasten a string-line to the starboard buffer board at station # 372.65 with fixture #1

b) Attach fixture #2 to the starboard buffer board at station # 535.00 and attach string-line

c) Use transit to locate fixture #3 inline with fixture #1 and #2 twenty feet aft of station #559

d) Attach string-line to fixture #3

e) Locate HTTV parallel to string-line

4) **Verify placement of cargo rollers and their effect on loading and unloading the HTTV** Time: 5min

a) Determine if the cargo rollers will be under the tire path

b) Verify the height of the cargo rollers and their effect on HTTV height

5) **HTTV loading** Time: 20min

a) Locate V-22 center of gravity and mark on deck with chalk

b) Measure ___" forward of V-22 CG and mark on decking with chalk

c) Drive HTTV forward into V-22

i) Raise the front of the HTTV three to four inches using HTTV ride height adjustment

ii) Mike Byerly will slowly drive the HTTV up the loading ramp and into the cargo area using instruction from the V-22 flight crew's assigned guide

iii) The closest points to the HTTV while it is entering the V-22 will be recorded

iv) While entering the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

v) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

vi) The HTTV will be driven forward until the front bumper on the HTTV has reached the predetermined stop line.

vii) The time that it took to load the HTTV will be recorded

viii) The HTTV will be shut off and Mike Byerly will exit the HTTV through the windshield

ix) The time that it takes to exit the HTTV will be recorded

6) **Measure clearances and document** Time: 20min

a) Note locations of tie-down stations
   i) Record the distance between station # ___ and the front bumper
   ii) Record the distance between station # ___ and the rear bumper
   iii) Record the distance between station # ___ and the driver front tire
   iv) Record the distance between station # ___ and the passenger front tire
   v) Record the distance between station # ___ and the driver rear tire
   vi) Record the distance between station # ___ and the passenger rear tire

b) Record location of any object within two inches of the HTTV

c) Record accessibility to HTTV equipment and personnel

d) Record remaining usable cargo area

e) Record location of any personnel seating that can be used

f) Record location of V-22 side exit doors in relationship to HTTV

g) Record distance between buffer board and all tires

h) Record distance between roof line of the HTTV and closest object

7) **Remove HTTV from V-22** Time: 10min

   i) Mike Byerly will enter the HTTV through the windshield
   ii) The time to enter the HTTV will be recorded
   iii) The HTTV will be started and Mike Byerly will slowly drive the HTTV out of the cargo area and down the ramp using instruction from the V-22 flight crew's assigned guide.
   iv) The closest points to the HTTV while it is exiting the V-22 will be recorded
   v) While exiting the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

vi) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

vii) The time that it took to unload the HTTV will be recorded

8) **Backing the HTTV into the V-22** Time: 15min

a) Measure ___" froward of V-22 CG and mark on decking with chalk

b) Drive HTTV backwards into V-22

   i) Raise the rear of the HTTV three to four inches using HTTV ride height adjustment

   ii) Mike Byerly will slowly back the HTTV up the loading ramp and into the cargo area using instruction from the V-22 flight crew's assigned guide

   iii) The closest points to the HTTV while it is entering the V-22 will be recorded

   iv) While entering the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

   v) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

   vi) The HTTV will be driven in reverse until the rear bumper on the HTTV has reached the predetermined stop line.

   vii) The time that it took to load the HTTV will be recorded

   viii) The HTTV will be shut off and Mike Byerly will exit the HTTV through the windshield

   ix) The time that it takes to exit the HTTV will be recorded

9) **Measure clearances and document** Time: 20min

a) Note locations of tie-down stations

   i) Record the distance between station # ___ and the front bumper

   ii) Record the distance between station # ___ and the rear bumper

   iii) Record the distance between station # ___ and the driver front tire

   iv) Record the distance between station # ___ and the passenger front tire

   v) Record the distance between station # ___ and the driver rear tire

vi) Record the distance between station # ___ and the passenger rear tire

b) Record location of any object within two inches of the HTTV

c) Record accessibility to HTTV equipment and personnel

d) Record remaining usable cargo area

e) Record location of any personnel seating that can be used

f) Record location of V-22 side exit doors in relationship to HTTV

g) Record distance between buffer board and all tires

h) Record distance between roof line of the HTTV and closest object

10) **Remove HTTV from V-22** Time: 5min

i) Mike Byerly will enter the HTTV through the windshield

ii) The time to enter the HTTV will be recorded

iii) The HTTV will be started and Mike Byerly will slowly drive the HTTV out of the cargo area and down the ramp using instruction from the V-22 flight crew's assigned guide.

iv) The closest points to the HTTV while it is exiting the V-22 will be recorded

v) While exiting the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

vi) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

vii) The time that it took to unload the HTTV will be recorded

11) **Backing the HTTV into the V-22 in preparation for guns up attempt #1** Time: 10min

a) A passenger will be added to the gunner position

b) Place the vehicle in reverse and drive HTTV backwards into V-22

i) Raise the rear of the HTTV three to four inches using HTTV ride height adjustment

ii) Mike Byerly will slowly back the HTTV up the loading ramp and into the cargo area using instruction from the V-22 flight crew's assigned guide

iii) While entering the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

iv) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

v) The HTTV will be driven in reverse until the rear bumper on the HTTV has reached the predetermined stop line.

vi) The time that it took to load the HTTV will be recorded

12) **Remove HTTV from V-22 and raise gun into position attempt #1** Time: 5min

i) Mike Byerly will drive the HTTV out of the cargo area and down the ramp using instruction from the V-22 flight crew's assigned guide.

ii) While exiting the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

iii) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

iv) The "gunner' will pop up through the gun ring and attempt to raise the gun and lock in place

v) After the gun is locked into place the ring pin will be pulled and the gunner will spin the gun into position

vi) The time that it took to unload the HTTV and raise the gun will be recorded

13) **Lower gun into resting position** Time: 5min

14) **Backing the HTTV into the V-22 in preparation for guns up attempt #2** Time: 10min

a) A passenger will be added to the gunner position

b) Place the vehicle in reverse and drive HTTV backwards into V-22

   i) Raise the rear of the HTTV three to four inches using HTTV ride height adjustment

   ii) Mike Byerly will slowly back the HTTV up the loading ramp and into the cargo area using instruction from the V-22 flight crew's assigned guide

iii) While entering the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

iv) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

v) The HTTV will be driven forward until the rear bumper on the HTTV has reached the predetermined stop line.

vi) The time that it took to load the HTTV will be recorded

15) Remove HTTV from V-22 and raise gun into position attempt #2 Time: 5min

i) Mike Byerly will drive the HTTV out of the cargo area and down the ramp using instruction from the V-22 flight crew's assigned guide.

ii) While exiting the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

iii) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

iv) The "gunner' will pop up through the gun ring and attempt to raise the gun and lock in place

v) After the gun is locked into place the ring pin will be pulled and the gunner will spin the gun into position

vi) The time that it took to unload the HTTV and raise the gun will be recorded

16) Lower gun into resting position Time:5min

17) Restraining harness installation Time:1hr

a) Layout restraining harness on the deck of the V-22
b) Fasten harness to tie-down stations using load limiters and ratchet straps
c) Properly tension all straps
d) Attach pulley system to restraining harness
e) Attach side straps to side of cargo area using bungee cords

18) HTTV loading Time: 10min

a) Drive HTTV forward into V-22
   i) Raise the front of the HTTV three to four inches using HTTV ride height adjustment
   ii) Mike Byerly will slowly drive the HTTV up the loading ramp and into the cargo area using instruction from the V-22 flight crew's assigned guide
   iii) While entering the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.
   iv) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.
   v) The HTTV will be driven forward until the front bumper on the HTTV has reached the predetermined stop line.
   vi) The time that it took to load the HTTV will be recorded
   vii) Mike Byerly will need to attach the side straps to the HTTV before exiting
   viii) The HTTV will be shut off and Mike Byerly will exit the HTTV through the windshield area
   ix) The time that it takes to exit the HTTV will be recorded

19) Attaching restraining harness to HTTV Time:10min

a) Lower and lock the HTTV lifting hooks into harness
b) Tighten the HTTV lifting hooks to the proper tension
c) Attach the HTTV winch to the pulley system
d) Tension pulley system using the winch

20) Harness measurements Time:15min

a) Record the distance between the cargo deck and restraining harness
b) Record any interference's between tie-down straps and the HTTV
c) Record distance between harness and HTTV

d) Record the distance between station # ____ and the front center point of the restraining harness

e) Record the distance between the station #___ and the rear center point of the restraining harness

f) Record any deflections of the harness after tensioning

21) Rear cargo hatch clearance test Time:20min

a) Make necessary preparations for closing the cargo ramp
b) Close the ramp
c) Record clearances between ramp and HTTV
d) Record any clearance issues involving personnel and access to ramp controls
e) Record remaining usable cargo volume

22) Open ramp and make necessary preparations for unloading cargo Time:15min

23) Detach restraining harness from HTTV Time:20min

a) Loosen pulley system using the winch
b) Detach the HTTV winch from the pulley system
c) Lower and release the HTTV lifting hooks from the harness

24) Remove HTTV from V-22 Time: 15min

i) Mike Byerly will enter the HTTV through the windshield
ii) The time to enter the HTTV will be recorded
iii) The side restraining straps will need to be removed from the HTTV and hung on the side of the V-22 cargo area using bungee cords
iv) The HTTV will be started and Mike Byerly will slowly drive the HTTV out of the cargo area and down the ramp using instruction from the V-22 flight crew's assigned guide.

v) While exiting the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

vi) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

vii) The time that it took to unload the HTTV will be recorded

25) Harness disassembly Time:30min

a) Detach side straps and bungee cords from the side of the V-22

b) Disassemble pulley system

c) Detach harness from V-22 deck by loosening the ratchet straps holding the harness

d) Remove restraining harness and ratchet straps from V-22

26) **Remove HTTV from V-22** Time: 10min

i) Mike Byerly will enter the HTTV through the windshield

ii) The time to enter the HTTV will be recorded

iii) The HTTV will be started and Mike Byerly will slowly drive the HTTV out of the cargo area and down the ramp using instruction from the V-22 flight crew's assigned guide.

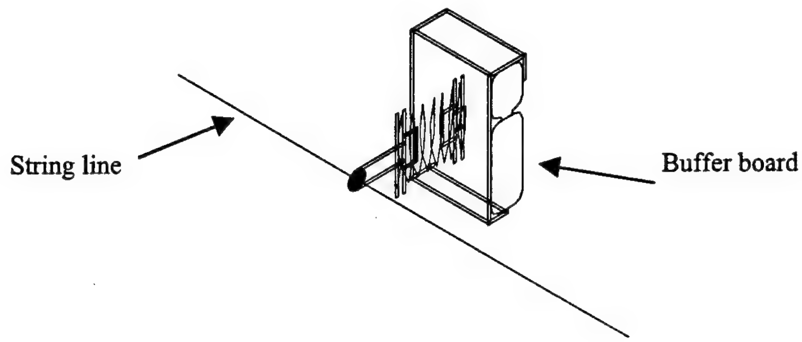
iv) The closest points to the HTTV while it is exiting the V-22 will be recorded

v) While exiting the V-22 Dave Fish will instruct Mike Byerly in raising and lowering the HTTV.

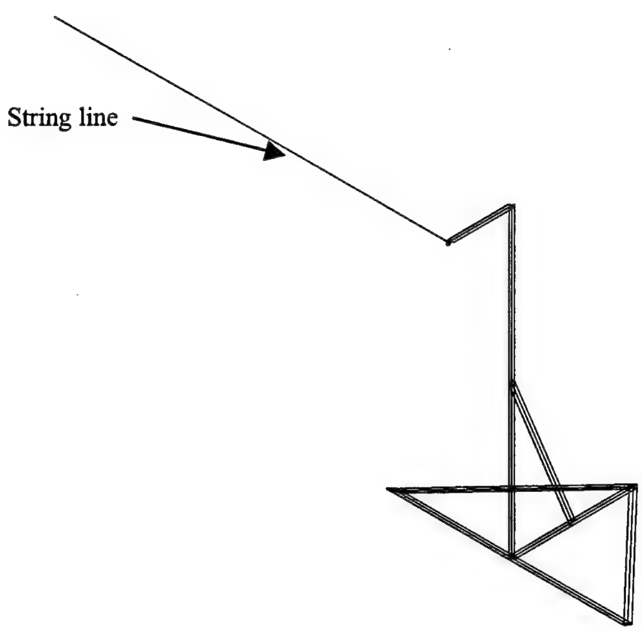
vi) Jeff Bradel, Dave Fish, and the V-22 flight test crew will watch from the corners of the HTTV for any clearance issues.

vii) The time that it took to unload the HTTV will be recorded

Drawing Fixture #1 and #2



Drawing Fixture #3



Appendix C

New River Test Results

Ramp Angle 20 Degrees
114" from the ground to the V-22 ramp vertex
Good weather
During the forward facing test the measurements were taken with the vehicle ride height all the way up.
During the rearward-facing test the measurements were taken with the vehicle ride height all the way down and with three passengers in the vehicle.

HTTV Facing Forward in relationship to V-22

- 1.5" from Driver side rear panel to seats
- 3.5" from Passenger side rear panel to seats
- 43.25" from V-22 cargo deck to Rear deck plates on HTTV
- Vehicle was loaded with the suspension lowering components installed
- Rear bar of the water can rack is at the 515" mark
- There are two 10,000 Lb. tie-down points behind water can rack
- 19' from water can rack to 10,000 Lb. tie-downs
- 45" from water can rack to 559" mark
- 69.5" from 559" mark to wheel edge
- 5.5" from Passenger side front panel to seat
- 6" from Driver side front panel to seat
- 319" mark is where the vehicle front bumper needs to be
- Vehicle had 2" of ground clearance at it's lowest point when exiting the V-22
- 2.125" clearance between Passenger side of the HTTV and the door gasket
- .75" clearance between Driver side of the HTTV and the door gasket

HTTV Facing Rearward in relationship to V-22

- 1.5" from Driver side rear panel to seats
- 5.25" from Passenger side rear panel to seats
- 6.75" from cargo deck to rear skid pan.
- 6.5" from cargo deck to front skid pan
- Vehicle was loaded with the suspension lowering components installed
- 42.75" from rear bumper to station 559
- Vehicle is fairly straight in the cargo area
- 37.75" from the driver side front role bar to V-22 cargo deck
- 37" from the passenger side front role bar to V-22 cargo deck
- The distance between station #309 and the rear bumper is 18.75"

Appendix D

Pax River Test Results

The measurements taken were with the vehicle backed into the V-22
The vehicle is out of the cargo envelope to the passenger side while backed in.

- The rear deck height of the HTTV is 46.5"
- There is 3.625" between frame #352.8 and the passenger side of the vehicle
- There is 10.125" between frame #352.8 and the driver side of the vehicle
- There is 4" between frame #371.1 and the passenger side of the vehicle
- There is 9.75" between frame #371.1 and the driver side of the vehicle
- There is 5.5" between frame #396.4 and the passenger side of the vehicle
- There is 9.875" between frame #396.4 and the driver side of the vehicle
- There is 3.125" between frame #421.4and the passenger side of the vehicle
- There is 8.375" between frame #421.4and the driver side of the vehicle
- There is 4.3125" between frame #439.6and the passenger side of the vehicle
- There is 6.25" between frame #439.6 and the driver side of the vehicle
- There are 33.375" inches between the roller Trays
- The exterior dimensions of the roller trays measure 40.625"
- The distance off the cargo deck to the hook mounts on the HTTV is 19.75" on the passenger side
- The distance off the cargo deck to the hook mounts on the HTTV is 20.125" on the driver side

HTTV #1 Center of Gravity Worksheet

Condition 1

- Curb Weight as Measured at Aberdeen
- Center of gravity data as measured on 18 Sept. 1998 at Aberdeen Proving Ground
- Original Rod Millen rims and tires
- Vehicle suspension lowered but without suspension adjusters in place
- Vehicle at curb weight (VCW) (vehicle empty, fuel tank full, on weapon)
- Longitudinal distance between axles is 119.28 inches
- Transverse distance between wheel centerlines is 53.25 inches
- Vehicle front skid plate is 10.75 inches above floor

Moments Calculated below from Aberdeen Wheel Load measurements

Wheel	Left Side	Right Side	Both Sides
Front	1318	1368	2686
Rear	1052	1070	2122
Total	2370	2438	4808

Longitudinal Moment :

	Left Side	Right Side	Both Sides
Front	157211.04	163175.04	320386.08
Rear	0	0	0
Total	157211.04	163175.04	320386.08

Transverse Moment :

	Left Side	Right Side	Both Sides
Front	-70183.5	72846	2662.5
Rear	-56019	56977.5	958.5
Total	-126202.5	129823.5	3621

Data as Presented by Aberdeen:

TCG	0.36 in.	Positive to the right of vehicle centerline
LCG	66.65 in.	Positive is forward of rear axle centerline
VCG	25.98 in.	Positive is the distance above the ground plane

Units are in inches, pounds, and inch-pounds.

HTTV #1 Center of Gravity Worksheet

Appendix F

Condition 2

- Combat Weight as Measured at Aberdeen
- VCG calculated based on VCG of Aberdeen test weights
- Center of gravity data as measured on 18 Sept. 1998 at Aberdeen Proving Ground with **2435 Lbs. of payload (except VCG)**
- Original Rod Millen rims and tires
- Vehicle **suspension lowered but without suspension adjusters** in place (rear raised)
- Vehicle suspension assumed to have spring rate of 300lbs/inch at each wheel = 2400 lbs./inch total (droop is 2.0 inches due to load)
- Vehicle weighted by 3-crewmembers weighted at 235 lbs., Radios, Weapon, Ammo, Water
- **VCG of payload assumed to be 33 inches** since measured value was not given – artificially low due to steel plate.
- Longitudinal distance between axles is 119.28 inches
- Transverse distance between wheel centerlines is 53.25 inches
- Vehicle front skid plate is 8.75 inches above floor

Moments Calculated below from Aberdeen Wheel Load measurements

Wheel	Left Side	Right Side	Both Sides
Front	1450	1590	3040
Rear	2070	2150	4220
Total	3520	3740	7260

Longitudinal Moment :	Left Side	Right Side	Both Sides
Front	172956	189655.2	362611.2
Rear	0	0	0
Total	172956	189655.2	362611.2

Transverse Moment :	Left Side	Right Side	Both Sides
Front	-70183.5	72846	2662.5
Rear	-56019	56977.5	958.5
Total	-187440	199155	11715

VCG Calculation:		Weight	Moment
	From Condition 1	4808	115295.8
	Added	2435	80355
	Total	7243	195650.8

Data as Presented by Aberdeen:

TCG	1.61 in.	Positive to the right of vehicle centerline
LCG	49.95 in.	Positive is forward of rear axle centerline
VCG	27.01 in.	Positive is the distance above the ground plane

Units are in inches, pounds, and inch-pounds.

HTTV #1 Center of Gravity Worksheet

Condition 3

- Combat Weight as Measured at Aberdeen
- VCG calculated based on VCG of Aberdeen test weights
- Center of gravity data as measured on 18 Sept. 1998 at Aberdeen Proving Ground with **2435 Lbs. of payload (except VCG)**
- Original Rod Millen rims and tires
- Vehicle **suspension lowered but without suspension adjusters** in place (rear raised)
- Vehicle suspension assumed to have spring rate of 300Lbs/inch at each wheel = 2400 lbs./inch total (droop is 2.0 inches due to load)
- Vehicle weighted by 3-crewmembers weighted at 235 lbs., Radios, Weapon, Ammo, Water
- **VCG of payload assumed to be 41.75 inches** for realistic cargo load
- Longitudinal distance between axles is 119.28 inches
- Transverse distance between wheel centerlines is 53.25 inches
- Vehicle front skid plate is 8.75 inches above floor

Moments Calculated below from Aberdeen Wheel Load measurements

Wheel	Left Side	Right Side	Both Sides
Front	1450	1590	3040
Rear	2070	2150	4220
Total	3520	3740	7260

Longitudinal Moment :	**Left Side**	**Right Side**	**Both Sides**
Front	172956	189655.2	362611.2
Rear	0	0	0
Total	172956	189655.2	362611.2

Transverse Moment :	**Left Side**	**Right Side**	**Both Sides**
Front	-70183.5	72846	2662.5
Rear	-56019	56977.5	958.5
Total	-187440	199155	11715

VCG Calculation:		**Weight**	**Moment**
	From Condition 1	4808	115295.8
	Added	2435	101661.3
	Total	7243	216957.1

Data as Presented by Aberdeen:

TCG	1.61 in.	Positive to the right of vehicle centerline
LCG	49.95 in.	Positive is forward of rear axle centerline
VCG	29.95 in.	Positive is the distance above the ground plane

Units are in inches, pounds, and inch-pounds.

HTTV #1 Center of Gravity Worksheet

Condition 4

- Combat Weight as Measured at Aberdeen
- **Center of gravity data recalculated with 2435 lb. payload, new wheels/rims and suspension adjusters in place**
- **Difference between new and old rim/wheel weight is +4 lbs./wheel**
- Original Rod Millen rims and tires
- Vehicle **suspension lowered but with suspension adjusters** in place – vehicle lowered 3.75 inches
- Vehicle suspension assumed to have spring rate of 300Lbs/inch at each wheel = 2400 lbs./inch total (droop is 2.0 inches due to load)
- Vehicle weighted by 3-crewmembers weighted at 235 lbs., Radios, Weapon, Ammo, Water
- **VCG of payload assumed to be 38 inches** for realistic cargo load
- Longitudinal distance between axles is 119.28 inches
- Transverse distance between wheel centerlines is 50.63 inches
- Vehicle front skid plate is 5 inches above floor

Moments Calculated below from Aberdeen Wheel Load measurements

Wheel	Left Side	Right Side	Both Sides
Front	1454	1594	3048
Rear	2074	2154	4228
Total	3528	3748	7276

Longitudinal Moment :	Left Side	Right Side	Both Sides
Front	173433.12	190132.32	363565.44
Rear	0	0	0
Total	173433.12	190132.32	363565.44

Transverse Moment :	Left Side	Right Side	Both Sides
Front	-73616.02	80704.22	7088.2
Rear	-105006.62	109057.02	4050.4
Total	-178622.64	189761.24	11138.6

VCG Calculation:	Weight	Moment
From Condition 1	4808	115295.8
Added	2435	101661.3
Wheel correction	16	275.2
Total	7259	190071

Data as Presented by Aberdeen:

TCG	1.53 in.	Positive to the right of vehicle centerline
LCG	49.97 in.	Positive is forward of rear axle centerline
VCG	26.18 in.	Positive is the distance above the ground plane

Units are in inches, pounds, and inch-pounds.

HTTV #1 Center of Gravity Worksheet

Appendix I

Condition 4

- Combat Weight as Measured at Aberdeen
- **Center of gravity data recalculated with 2435 lb. payload, new wheels/rims and suspension adjusters in place**
- **Difference between new and old rim/wheel weight is +4 lbs./wheel**
- Original Rod Millen rims and tires
- Vehicle **suspension raised but with suspension adjusters** in place – offset from lowered position to raised position with same loading is 4.5 inches
- Vehicle suspension assumed to have spring rate of 300Lbs/inch at each wheel = 2400 lbs./inch total (droop is 2.0 inches due to load)
- Vehicle weighted by 3-crewmembers weighted at 235 lbs., Radios, Weapon, Ammo, Water
- **VCG of payload assumed to be 42.5 inches** for realistic cargo load
- Longitudinal distance between axles is 119.28 inches
- Transverse distance between wheel centerlines is 50.63 inches
- Vehicle front skid plate is 9.5 inches above floor

Moments Calculated below from Aberdeen Wheel Load measurements

Wheel	Left Side	Right Side	Both Sides
Front	1454	1594	3048
Rear	2074	2154	4228
Total	3528	3748	7276

Longitudinal Moment :	Left Side	Right Side	Both Sides
Front	173433.12	190132.32	363565.44
Rear	0	0	0
Total	173433.12	190132.32	363565.44

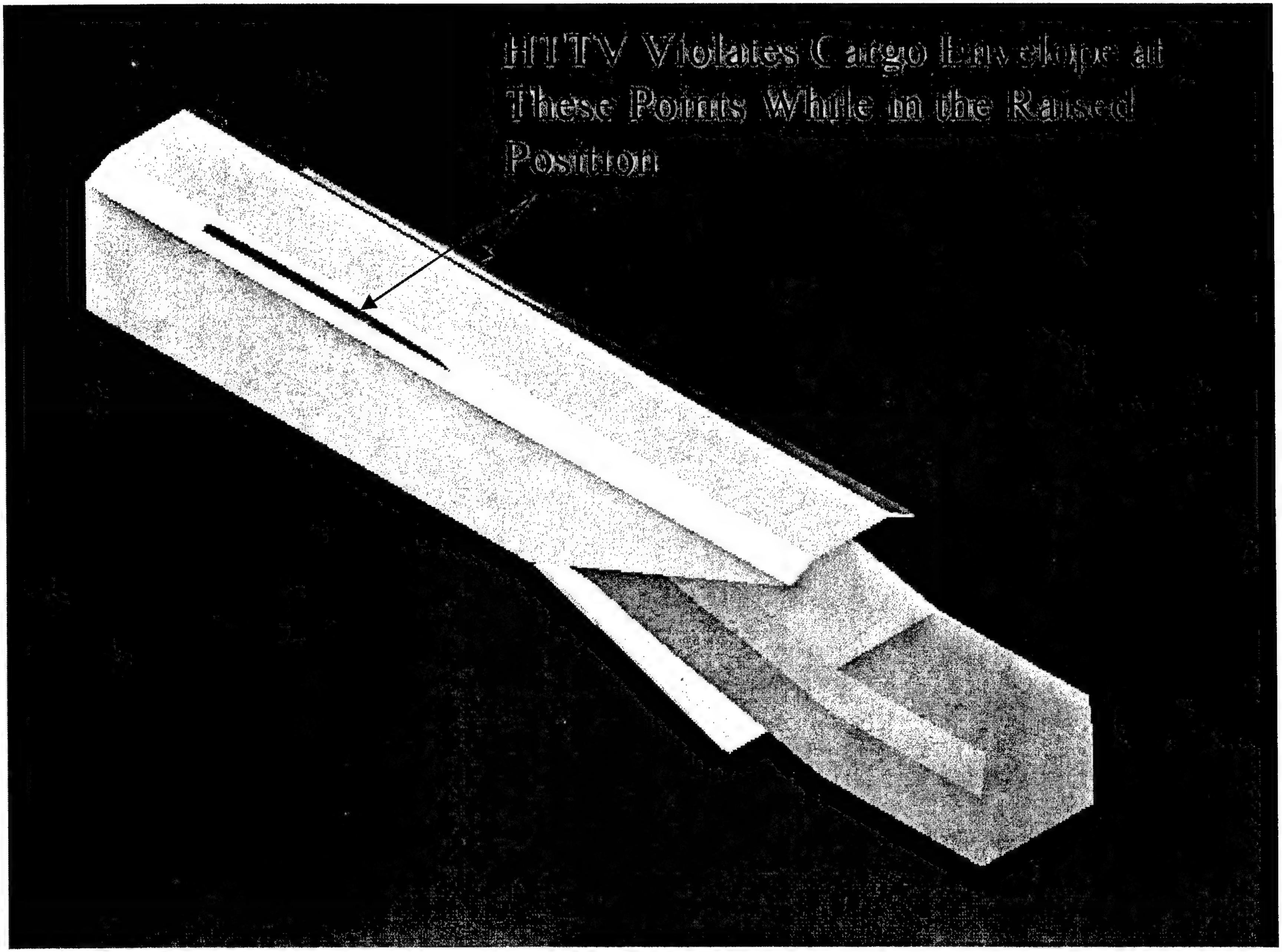
Transverse Moment :	Left Side	Right Side	Both Sides
Front	-73616.02	80704.22	7088.2
Rear	-105006.62	109057.02	4050.4
Total	-178622.64	189761.24	11138.6

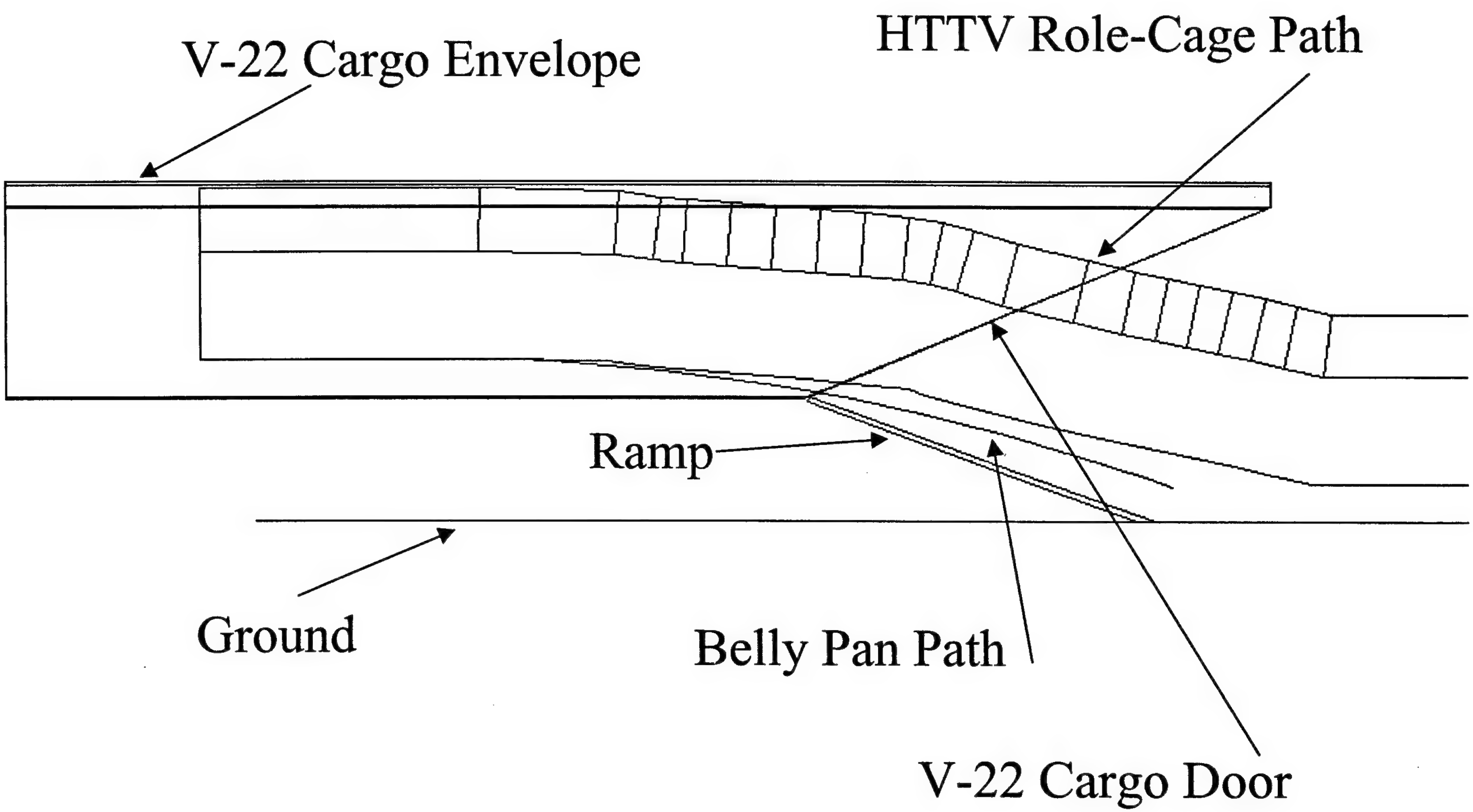
VCG Calculation:		Weight	Moment
	From Condition 1	4808	115295.8
	Added	2435	101661.3
	Wheel correction	16	275.2
	Total	7259	222664.5

Data as Presented by Aberdeen:

TCG	1.53 in.	Positive to the right of vehicle centerline
LCG	49.97 in.	Positive is forward of rear axle centerline
VCG	30.67 in.	Positive is the distance above the ground plane

Units are in inches, pounds, and inch-pounds.


HTTV Violates Cargo Envelope at
These Points While in the Raised
Position


V-22 Cargo Envelope
HTTV Role-Cage Path
Ramp
Ground
Belly Pan Path
V-22 Cargo Door

Appendix H

V-22 Aircraft Fitcheck #3 (Guide Rail Concept Issues Report)

18 Dec 98

Memorandum

From: MSGT Todd Anderson, V-22 MOTT
Mr. Larry Smith, V-22 ITT

To: CDR D. Schwartzenburg, V-22 Class Desk
LCOL M. Morgan, V-22 Deputy APM SE
LCOL J. Rudzis, V-22 GFTD
Mr. D. St. Jean, V-22 Deputy Class Desk
Mr. J. Carbonaro, V-22 ITT Lead Engineer
Mr. N. Runowich, NAWCAD Cargo Handling IPT Leader
Mr. K. Eland, Bell-Boeing
Mr. Jeff Bradel, NSWCAD Carderock
Mr. Jim Cerulli, III, MAPC

Subj: Integration of Vehicle Guide System for V-22

Background.

1. The Vehicle Guide System was evaluated on V-22 A/C 2 using the Helicopter Transportable Tactical Vehicle (HTTV). The test was conducted in approximately 2 hours at NAWCAD-PAX, Patuxent River, MD on 16 December 1998. NSWC Carderock has been tasked with developing a tactical vehicle that is compatible with the V-22. The tactical vehicle Operational Requirements Document (ORD) specifies time required for loading and unloading. The purpose of this test was to demonstrate the concept of a vehicle guide system and identify issues with this configuration. The intent of the vehicle guide system is to meet the loading and unloading time requirements of the vehicle ORD and reduce the potential for aircraft damage while loading and unloading the tactical vehicle.

Description.

2. Vehicle Description. The vehicle guide system was designed quickly and crudely manufactured to demonstrate this concept. The vehicle guide system was constructed out of aluminum C-channel. Two C-channels were welded together to form a piece that fit into the roller rail tray channels and provided a 5 inch tall rub surface for the tires. The roller rails were removed from the aircraft to accommodate the vehicle guide system. The guide system was built in four sections, 3 sections for the cabin and 1 section for the ramp. The guide rails were designed to guide the inner side wall of the vehicle tires. The guides were tapered near the ramp hinge area for maximum vehicle clearance as shown in figures 1 and 2.

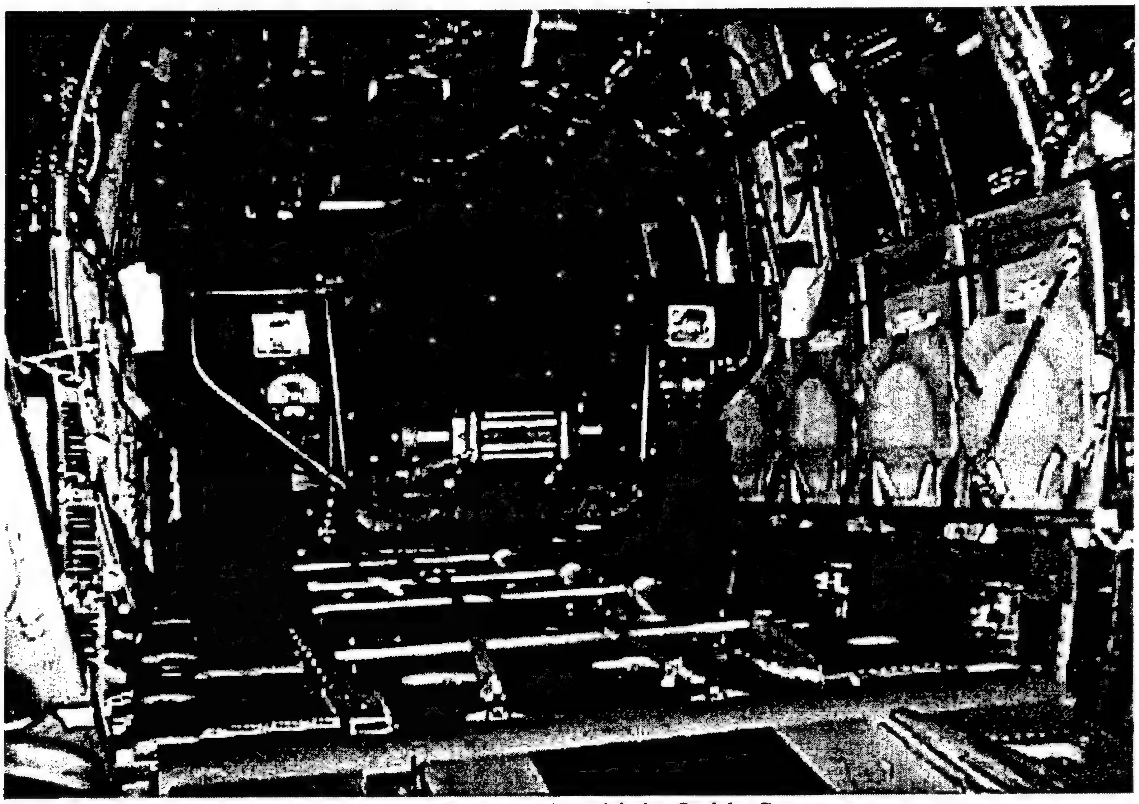


Figure 1: HTTV and Vehicle Guide System

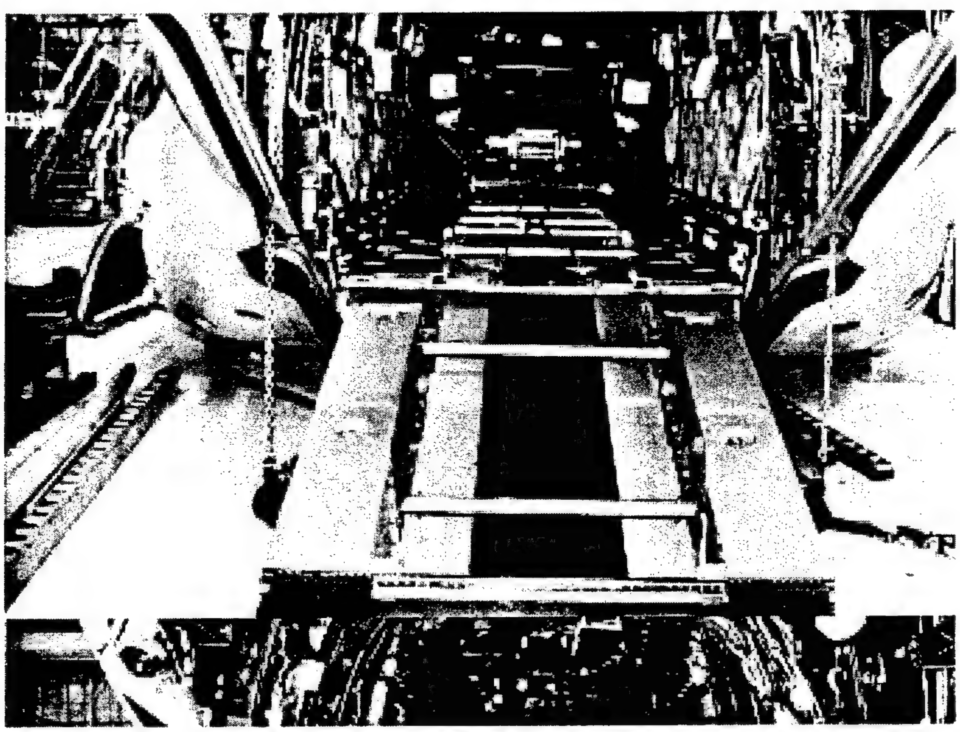


Figure 2: HTTV and Vehicle Guide System

3. Aircraft Description. V-22 Full Scale Development A/C 2 was used for this test. The aircraft was missing the wing and numerous other parts have been removed. The landing gear were serviced as required but was not representative of a normal servicing. The ramp angle was less than the nominal EMD ramp angle. Also, the ramp break over angle became less as the vehicle was loaded due to the compression of the MLG struts.

Method.

4. The test was conducted first installing the vehicle guide system in A/C 2 and securing the sections in the cabin to the floor using 4 tie down straps. The vehicle was loaded forward and backward. The vehicle was also loaded with a slight misalignment.

Results.

5. Vehicle Aligning and Guiding. The HTTV was loaded 4 times in the forward direction and 4 times in the backward direction with the vehicle guide system installed into the roller rail trays. The guides aligned and centered the vehicle reducing the risk of contacting the side of the aircraft and therefore, reduced the number of steering commands and clearance checks the crew chief would normally perform when loading a vehicle without a guide system. During one event, a vehicle tire began to ride up on the guide system near the ramp hinge area. At the ramp hinge area the guide system height was tapered to provide undercarriage clearance. The crew chief backed the vehicle up, realigned the tires and completed the loading. Using the guide system turned loading the HTTV into a one crew chief job instead of two or more. Reducing the risk of contacting the side of the aircraft reduced the crew chief work load resulted in quicker loading and unloading events. Recommend investigating a means to restrain the vehicle to the guide system. Recommend Bell-Boeing analyze the roller rail trays for the loads that the vehicle guide system may impart into the airframe.

6. Interference with Seat Stroke. The vehicle guide system was raised approximately 5 inches above the floor. If troop seats are used with the vehicle guide system installed, in the event of an accident the vehicle guide system will prevent the troop seat from stroking to the floor. Recommend the vehicle guide system not interfere with the seat stroke.

7. Mission Flexibility. The USAF SOCOM mission is a single task unlike the USMC mission where each leg of the flight might be something different, for example, external loads which might be followed by troop transport which might follow internal loads. Loading the HTTV will be easier using the vehicle guide system but the guide system will prevent the USMC from conducting any other USMC mission without excessive crew compensation. Installing the vehicle guide system requires removing the roller rails from the aircraft. The vehicle guide system was made specifically for the HTTV and will not be compatible with any other vehicles unless the width between the tire inside sidewalls are the same or greater and the undercarriage clearances are the same or greater. Recommend investigating integrating the vehicle guide system into the airframe to reduce impact to USMC primary missions.

8. Vehicle Contacted ECS Duct. The HTTV was positioned in the aircraft facing aft. The HTTV was unloaded. During the unloading the roll cage on the left side of the vehicle contacted the most aft vent on the RH ECS duct. The vent was partially pulled out of the retaining clip. No other damage was observed. The HTTV roll cage has not been optimized for the V-22 but plans exist to increase the clearance between the vehicle roll cage and the aircraft in the next tactical vehicle prototype. Recommend NSWC Carderock ensures the HTTV does not exceed the V-22 cargo envelope.

9. Vehicle suspension. The HTTV has an adjustable suspension. The lowest the suspension could be positioned and still provide sufficient undercarriage clearance between the vehicle and the vehicle guide system was 1.5 inches from full down. The HTTV was not configured with a load. A mission load on the HTTV will vary the undercarriage clearances. Recommend ensuring that clearances will be maintained with a loaded HTTV and an empty HTTV.

10. Ramp vehicle guide structure. The HTTV was loaded onto V-22 A/C 2 using the vehicle guide system. The ramp vehicle guide structure was not restrained to the ramp. As the HTTV was loaded and the tires would rub against the guide, the guide would lift out of the track. The ramp vehicle guide fell back into place. However, some form of restraint will be required. Recommend investigating restraining methods for the vehicle guide system on the ramp.

Sincerely,

Larry Smith

Appendix I

URBAN WARRIOR Experiment

For Official Use Only

Marine Corps Warfighting Laboratory

Urban Warrior
Limited Objective Experiment 1

Reconstruction and Operations Analysis Report

8 May 1998

By:

Dwight Lyons
John Goetke
Ken Lamon
Fred McConnell
Brian McCue
John Reynolds
Doug Turnbull
Capt Kevin Brown, USMC

For Official Use Only

5000
C 52
8 May 98

From: Commanding Officer, Marine Corps Warfighting Laboratory, Marine Corps Combat Development Command, 2042 Broadway Street, Suite 201, Quantico, VA 22134-5069

Subj: URBAN WARRIOR LOE 1 ANALYSIS REPORT

1. This report contains the reconstructions and operations/training analytical results of the Marine Corps Warfighting Laboratory Urban Warrior Limited Objective Experiment 1 (LOE 1). This experiment was conducted during the period 18-23 January 1998, in the Camp Lejeune, North Carolina Military Operations in Urban Terrain (MOUT) facility.

2. The analyses contained in this report reflect the best opinions of the Marine Corps, CNA, and contract personnel who performed the studies. This report is approved for release by the Marine Corps Warfighting Laboratory, but its results do not necessarily reflect Marine Corps' policy or doctrine, and are subject to further review and analysis as necessary.

3. This report is for official use only and may not be released outside the Department of Defense without prior approval from the Commandant of the Marine Corps.

Anthony A. Wood

ANTHONY A. WOOD
Colonel, USMC

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Table of Contents

Mobility Limited Technical Assessment (LTA)

Analysis Methodology

- **Pre-LTA:**
  - Develop LTA Objectives and identify Measures of Performance (MOPs)
  - Develop Data Collection Plan
  - Assign Analysis Team: two Analysts, six Observer/Controllers
- **During LTA:**
  - Collect Data related to MOPs
- **Post LTA:**
  - Compile MOPs
  - Compare vehicle types according to MOPs
  - Develop conclusions

The analysis methodology used during the Mobility LTA was as follows:

Prior to the LTA, the analyst and MCWL Mobility section developed LTA objectives and identified potential Measures of Performance (MOPs) which address those objectives. A data collection plan was also developed which identified essential data elements which needed to be collected to address the MOPs. Finally, an analysis team was built - consisting of two analysts, and six observer/controllers who were responsible for collecting data at key positions.

During the LTA, the observer controllers and analysts observed the LTA activities in and outside of the Mobility course, and collected data related to the MOPs.

After the LTA, the analysis report was written. First, the analyst compiled MOPs based on the data. Then, the various vehicle types used during the LTA (All-Terrain Vehicle (ATV), Gator, and Helicopter Transportable Tactical Vehicle (HTTV), and HMMWV) were compared on the basis of those MOPs. Finally, overall conclusions were developed about the LTA.

LTA Objectives

- Can we identify preferred small urban vehicle (SUV) characteristics for conducting resupply/medevac operations in urban terrain?
- Can we identify relative advantages and disadvantages of three different types of SUVs- the Grizzly, Gator, HTTV - as well as the HMMWV, in conducting resupply/medevac operations in urban terrain?
- Can we identify TTPs for Sustainment Delivery Teams (SDTs) to employ while using SUVs in urban operations?

For this LTA, several objectives were developed, as shown on this slide.

Measures Of Performance

- **Maneuverability**
- **Turning radius**
- **Speed on mobility course**
- **Max speed**
- **Helicopter internal transportability**
- **Payload capacity (max weight)**
- **Vulnerability on mobility course**

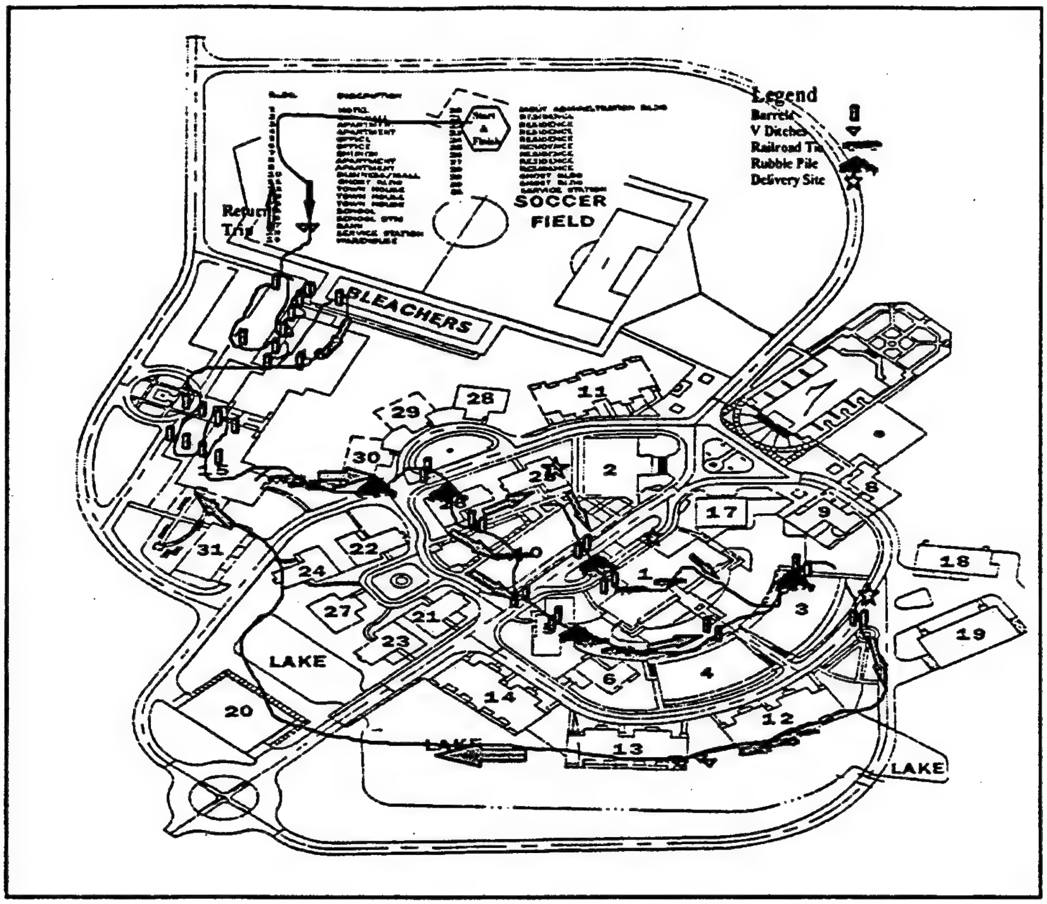
Prior to the LTA, several LTA MOPs were developed, as shown on the slide. The MOPs were the criteria on which the different vehicle types were compared These were developed to determine which vehicle types or characteristics are preferred for operating in urban areas.

Mobility Course Setup

- **Fixed course through MOUT site (see map on next page)**
- **Course Setup:**
  - 6 Stations: Gymkhana course, Close Confine Course, 3 resupply objectives, 1 medical evacuation objective
  - Along the route: Slit trenches, steps, rubble
- **SDT w/vehicle moves tactically through course**
- **Sandbags carried on vehicle and dropped off at objectives to replicate a "resupply load"**
- **4 OpFor snipers provide harassing fire from northern sector of MOUT site**

A mobility course was set up in the Camp Lejeune MOUT site (see map on next page). The course consisted of a fixed route which began at the north end of the site, wound through the built-up area, and finished at the original starting position. There were six primary stations on the course. The starting point was the first station, at which the total course completion time was collected. The second and third stations were the Gymkhana and Close Confine course, respectively, both of which consisted of several barrels and white engineer tape through and around which the vehicles had to make numerous tight turns - with course times and total barrels/tape hit collected there. At intermediate points along the course there were three resupply objectives (stations four to six) at which the SDTs had to drop off four to five sandbags: Objective 1 was building 25, Objective 2 was building 1, Objective 3 was building 19. At Objective 3, the SDT also had to pick up a casualty and move it over a short distance. At those stations, time to unload supplies/load casualties was collected. In addition to these six stations, the time for the SUVs to move from building 15 to main street was collected. Finally, the ground along the route was scattered with several trenches, steps, and rubble to stress the vehicles' ability to overcome obstacles.

During each vehicle run, a six-man SDT accompanied the vehicle and moved tactically through the MOUT site along the prescribed route. To ensure the SDT moved tactically, an OpFor element consisting of 4 snipers provided harassing fire from buildings in the northern sector of MOUT site. Analysts were positioned with the OpFor to measure exposure time of the SUVs so vehicle vulnerability could be evaluated.



The map of the mobility course is shown above. The blue arrows signify the prescribed movement route for all vehicle runs, except the three force-on-force runs.. The stars mark the three resupply objectives.

Mobility LTA Events

- **Outside the Mobility Course: Vehicle assessments on certain MOPs (i.e., turning radius).**
- **On the Mobility Course:**
- **(23) total vehicle runs (21 day/3 night) - breakdown by type of vehicle**
  - (7) ATV (1 w/trlr)
  - (7) Gator (1 w/trlr)
  - (7) HTTV (1 w/trlr)
  - (2) HMMWV

The events of the LTA were as follows:

Prior to the actual SUV runs on the Mobility Course, certain vehicle measurements were taken, such as turning radius, ground clearance, width, track.

During the main portion of the LTA, there were a total of twenty-three vehicle runs. Twenty-one of those runs were in daylight hours, and three were at night. The breakdown of these runs by type of vehicle is as follows:

No. Runs	Vehicle type
7	ATV (1 w/trlr)
7	Gator (1 w/trlr)
7	HTTV (1 w/trlr)
2	HMMWV

Mobility LTA Events (cont.)

- **23 total vehicle runs (breakdown by type of run)**
  - Runs 1 - 3: SUVs w/trailer/SDT
  - Runs 4 - 6: SUVs only/SDT
  - Runs 7 - 9: SUVs only/SDT/no snipers
  - Runs 10 - 13: SUVs + HMMWV only/no SDT/no snipers
  - Runs 14 - 16: SUVs only/SDT/unconstrained route & OpFor
  - Runs 17 - 20: SUVs + HMMWV only/SDT
  - Runs 21 - 23: SUVs only/SDT/night

The breakdown of vehicle runs by type of run is shown on the slide above. The runs were conducted in blocks where either all the SUVs or the SUVs and HMMWV were evaluated under varied circumstances. The first three runs were the only runs where trailers were attached to the SUVs. In runs 4 through 6, the SUVs with SDTs were evaluated. In runs 7 through 9, the SUVs with SDTs were evaluated with the OpFor disengaged. In runs 10 through 13, the SUVs and HMMWV were evaluated with no SDT nor OpFor. Runs 14 through 16 were more free-play oriented with the SDT and OpFor allowed to choose their routes, with the constant being that the SDT still had to resupply the three objectives. Runs 17 through 20 were run under the same circumstances as 4 through 6, with the addition of the HMMWV. Runs 21 through 23 were conducted at night with the SDTs and OpFor using night vision devices.

Mobility LTA MOPs

MOP/Veh	ATV	Gator	HTTV	HMMWV
Maneuverabi-lity	1	.73	.64	.39
Turning radius	1	.80	.52	.44
Speed on Mobility Course	1	.92	.88	.43
Speed (max)	1	.36	1	1

The MOPs provide a comparative assessment of the SUVs and the HMMWV based on certain criteria and are applicable for the circumstances used during this assessment only. Each MOP was derived using measurements taken during various evolutions during the LTA. In all MOPs, the most favorable vehicle type for that criteria was transformed into a 1, with less favorable vehicle measurements transformed to a scale from 0 to 1. Thus, rather than a strict ordinal ranking (1, 2, 3, 4), the relative variance between the vehicles' performance was captured (i.e.., 1, .85, .5, .2)

For the specific MOPs, raw data is shown below (normalized values are shown on the slide):

- Vehicle maneuverability was assessed using the average times on the Gymkhana course. The raw times were: ATV - 61 sec, Gator - 84 sec, HTTV - 95 sec, HMMWV - 155 sec.
- Vehicle turning radius (outer wheel to outer wheel) was measured outside of the Mobility course in an adjacent parking lot. Raw turning radius measurements were ATV - 252", Gator - 316", HTTV - 488", HMMWV - 576".
- Vehicle speed on the Mobility course was taken using the midpoint times (from Bldg. 15 to main street) during runs 10-13 (no SDT/no OpFor), with raw times being: ATV - 62 sec, Gator - 70 sec, HTTV - 75 sec, 156 sec.
- Vehicle max on-road speed was taken from the vehicle specifications, with speeds being: ATV - 55+, Gator - 20, HTTV - 55+, HMMWV - 55+.

Mobility LTA MOPs (cont.)

MOP/Veh	ATV	Gator	HTTV	HMMWV
Helicopter transportable	1	1	1	0
Payload capacity (wt)	.12	.4	.8	1
Vulnerability on Mobility Course	1	1	.4	.1

Continuing with the MOPs:

- Helicopter internal transportability was a simple yes/no issue, with all vehicles except the HMMWV scoring a 1 for yes, and the HMMWV scoring a 0 for no.
- Max payload capacity for supplies was taken from the vehicle specifications, with weights: ATV- 300lbs, Gator-1000lbs, HTTV-2000lbs, HMMWV - 2500lbs.
- Vehicle vulnerability on the mobility course was assessed by measuring the total time the vehicles were exposed to sniper fire during runs 15-18, with resultant scores of: ATV - 2 sec, Gator - 2 sec, HTTV - 5 sec, HMMWV - 20 sec.
- Vehicle survivability could not be addressed as a reasonable assessment could not be accomplished without actually firing on the vehicles.

SDT Comments on Vehicles

Vehicle Type	Advantages	Disadvantages
ATV	Good maneuverability	-Poor cargo capacity -LEDs on instrument panel blind the drive
Gator	-Good payload capacity -Good power -Good access to driver space	-Poor steering -Low ground clearance
HTTV	-Good power -Good obstacle clearing capability -Good ground clearance	-Poor cargo capacity -Driver/cargo space too tight
HMMWV	N/A	N/A

After the LTA, a group debriefing of the SDT Marines was conducted, with comments gathered on the advantages and disadvantages of the three SUV types (the HMMWV was not discussed). The assessment from this debrief is summarized in the table shown on the slide. The general assessment was that an optimal vehicle for operating in urban areas would incorporate the maneuverability of the ATV, a payload capacity no less than the Gator, and the power/ground clearance of an HTTV. Given a choice between the three vehicle types, the Gator was the most preferred in this LTA.

Force-on-Force runs

- **Runs 12-14 (ATV, Gator, HTTV)**
- **Free-play**
- **SDT tactics required**
  - Route planning
  - Obstacle clearing capability
  - 360 degree security while moving and halted
  - Unloading/loading procedures at objectives
- **Conclusion: SDTs can be made more survivable/effective with extensive training in force-on-force environment**

During runs 12 through 14, the mobility course was altered to allow the SDT and OpFor to move freely within the MOUT site, with the SDT's mission to resupply at the three objectives. The intent of this block of runs was to identify tactical areas related to SDTs. Some of these were: an ability to plan routes, to circumvent obstacles along that route, to provide 360 degree security while moving and while halted during resupply, and to use efficient procedures while unloading and loading at objectives.

The overall conclusion from conducting this series of runs was not so much a "score" result, but a comment on the value of the training provided: personnel almost uniformly reported that force-on-force training, even with a minimal OpFor presence, is highly effective in increasing SDT survivability and effectiveness. The SDTs were highly enthusiastic about the realism provided by these runs - and the venue it provided them for refining their procedures.

Recommendations for Further Study

- **Further assessments of upgraded vehicle types with additional MOPs:**
  - Casualty carrying capability
  - Firepower capability
  - Obstacle clearing capability
  - Survivability
- **Further refinement of SDT tactics, techniques, and procedures**
-

From this LTA, the need for further study of SUVs was demonstrated. There should be additional assessments of refined SUV variants which incorporate desirable characteristics of vehicles used during this LTA. In future analysis efforts, potential additional MOPs are: casualty carrying capability, firepower capability, obstacle clearing capability, and survivability, to name a few. Finally. the tactics, techniques, and procedures used by SDTs should be further refined and evaluated during subsequent evolutions.

Conclusions

- **Reduce vulnerability through increased maneuverability using smaller, not faster, vehicles.**
  - Don't need really fast vehicle in MOUT
  - The slowest vehicle (Gator - max speed 20 mph) tied with the ATV for lowest vulnerability
- **However, there is a major tradeoff between vulnerability and payload capacity.**
- **Gator was the most preferred vehicle, but payload capacity needs improvement (perhaps through an expanded cargo bed or trailer).**

Based on a review of the MOPs, the following conclusions can be drawn from this LTA:

If one considers the vulnerability of the SUVs to be the most important measure of vehicle performance which affects the SDT's ability to carry out its mission (overall effectiveness), then one should seek to reduce SUV vulnerability through increased maneuverability using smaller, not necessarily faster, vehicles. This LTA demonstrated that maximum vehicle speed is not as important as vehicle maneuverability in MOUT. The slowest vehicle, the Gator (max speed of 20 mph), tied with the ATV (max speed of 55+ mph, for the lowest vulnerability.

Nevertheless, in the vehicle types assessed during this LTA, there was a significant trade-off between vulnerability and payload capacity (indicative of the SUV's ability to carry supplies/casualties). The smaller, less vulnerable SUVs were far inferior in payload capacity to the larger, more vulnerable SUVs.

The type of SUV which performed the best all-around in the measures of performance was the Gator, which was clearly the vehicle type most preferred by the SDTs. Although the Gator's vulnerability was quite low, the vehicle's payload capacity could still use some improvement. Such improvement may come from expanding the cargo bed or adding a trailer, as long as those additions do not significantly decrease the Gator's maneuverability.

"Sea Dragon" Urban Warfare Training
January 18th – 25th

Introduction Between 18 and 25 January, the USMC tested four different mechanized platforms in a mission involving logistics support, under fire in an urban environment. The four including a six-wheeled vehicle known as "Gator", a "Grizzly" ATV, a HMMWV, and the HTTV were evaluated against each other in a number of similar scenarios. Each platform made timed runs through the Corps urban warfare training facility (M.O.U.T.) to determine its overall capabilities and limitations.

Mission Description During the urban warfare training exercise, the CSS Enterprise battalion provided logistics support to an infiltrating force. These services included resupplying munitions enclosed in a CSS Enterprise designed munitions pack, and transport of casualties out of the engagement zone.

The infiltrating forces were intended to have support provided by an attached logistics squad staged in a safe zone. When support was needed, the platoon requiring it would contact the squad through the support team's command and control group, who would in turn contact the squad. The squad would then proceed to the pick-up or drop-off point, using their own security team on a route that was chosen by the command and control group. They would supply munitions or pick up casualties at one or more points, then return to their staging area with the security team. (This was a very confusing process with the platoon commander and the logistics commander each giving directions to both groups. No one fully understood who was on what channel, or how to change channels, however they still managed to do a fairly good job of providing support). Three scenarios were usually run each day; two during the day and one at night. Most of the time one or two of the five man squad got "killed' and sometimes (especially with the Gator), the vehicle got "blown up". They were using laser sensing "MILES gear" to record "hits" which was intermittent. I suspect the attrition rate would have been even higher if the gear had been working properly.

Comparative Vehicle Performance The four mechanized platforms each had unique features and strengths.

GATOR-The six wheeled "Gator" had a payload capacity of 1500 lbs. yet was small enough to maneuver over and around most obstacles. The inherent properties of the vehicle drive train limit its steering/maneuvering capabilities when all 4 rear wheels are locked together to drive the platform. There is apparently insufficient traction in the steering (forward) tires to overcome the combined drive forces when in this mode (uses an anti-slip rear differential). The security team also had a hard time surpressing sniper fire for the duration needed to navigate the vehicle to a safe area due to its relatively low speed and acceleration capabilities. The Gator had two different types of trailers, both of which were poorly made.

GRIZZLY-An ATV which participated in the test was known as the "Grizzly". This vehicle is quick and agile and can maneuver in tight spaces much better than any of the vehicles tested. It was therefore easier to protect from sniper fire. However it is limited in its ability to carry large payloads.

HMMWV - The HMMWV had the largest load capacity of all the vehicles tested. However it had trouble negotiating small streets and was ineffective at maneuvering close to buildings or other structures. Because of its size, this platform was also hard for the security team to protect from sniper fire, and the HMMWV version used had poor visibility.

HTTV - The fourth vehicle tested was the HTTV. It performed well in the area of maneuvering around and over obstacles. It is however too large to maneuver through buildings which might be used (as in the case of the Grizzly) to gain cover and some advantage over the opponent. The security team was able to protect the vehicle easily due to the fact that the HTTV can maneuver quickly when needed. The HTTV, while having a large load capacity has some limitations on its usable cargo volume.

HTTV Details The USMC had a number of ideas for modifications to the HTTV, some of which have been suggested before, and some new ideas. The weapon mount on the HTTV proved to be a very valuable asset to the logistics team, even though occupying it impacts cargo volume. They mounted the new M240G Medium Machine Gun on the vehicle and used it to provide security for the squad. They could have also used a dash weapons mount for either an M16 or M249 SAW. Instead the driver was trying to drive and use a handheld weapon with one hand. This was not particularly effective. The experimental battalion; CSS Enterprise would have also liked to have had a mount for a Tube Launched, Optically Tracked, Wire Guided (TOW) missile system, or possibly a 40mm low recoil gun mount.

The FLIR was one of the most talked about features on the vehicle. Everyone was amazed with the image resolution / detail available with this system. The FLIR easily pinpointed snipers hiding in or on buildings. For operations in total darkness, the image on the display was clear enough to drive by, and to give directions to an aircraft dropping equipment and personnel. There were questions about how to elevate the FLIR to gain a better viewpoint. [A quiet (i.e. electric or pneumatic} telescoping mast is the obvious answer]. The Corps would like to see a laser guided targeting system slaved to the FLIR with firing capability similar to the systems on the M1 tank.

Shortfalls The HTTV as currently configured was an excellent performer, but may not yet be the optimum solution to a need for a logistics support vehicle. The confined cargo volume in the current configuration clearly limits the utility of the HTTV. Currently this is traded off against the security role which the vehicle handles well. The constrained urban scenario also doesn't allow the HTTV to show some of its strongest features since there was little opportunity to use the high-speed capability where the vehicle excels. Also the limited training that the squads received in vehicle operation precluded them from taking advantage of all of its features. In the future the Corps would like an integrated electronics / communication package that gathers optical images and transmits them to a special operations command center, and an automated tracking and designating system.

Appendix J

User Evaluations and Payload Experiment

Appendix K

Fuel Efficiency Testing with the Joint Tactical Electric Vehicle

Appendix L

URBAN WARRIOR Experiment

URBAN WARRIOR ASSESSMENT CONFERENCE CAPABILITY BRIEF
25 May 99(1530)

CAPABILITY/TECHNOLOGY: **FLYER VEHICLE(LIGHT STRIKE VEHICLE)**

1. GENERAL. The area enhanced is Mobility/Countermobility and Sustainment as defined in MCCDC MOUT Concept Paper.

2. DESCRIPTION. A non-developmental item(NDI). The missions the Light Strike Vehicle(LSV)can perform are numerous (raids,C2,weapons, logistics). The LSV replaces the Fast Attack Vehicle (FAV) currently employed throughout the Marine Air Ground Task Force (MAGTF). The standard mission distance is a round trip of 140 miles over all types of terrain.

3. EMPLOYMENT. The LSV was used only in the AWE for Urban Warrior. There were five training evolutions at Camp Pendleton CA. and MCAS, El Torro CA. that demonstrated embarkation and weapons capability. Additionally it provides a heliborne unit organic mobility and logistics capacity.

4. ANALYSIS. None.
(Results)

5. RESOURCES EXPENDED.

a. Expended ($10,000 FY 99)
b. Obligated this year ($10,000)
c. Expended this year ($10,000)
d. Programmed for future years- 0

6. ASSESSMENT. Everyone to include CG MCCDC and CG MCWL were impressed by the LSV. It is the best vehicle we have seen tested and transported by tactical aircraft. The shortfalls expressed by the CSSE Commander were; needs to have more fording capability, additional cargo room, a windshield, and weather and ballistic protection.

7. PROPOSED EXPLOITATION COA. Continued Examination. Not throughly experimented with during the Urban Warrior experimentation process, but shows enough promise to warrant further examination with Operating Forces (MEU's).

Devin Maj Timothy J

From: MCWL-MDS
Sent: Wednesday, February 10, 1999 8:29 AM
To: MCWL All Messages
Subject: FLYER 21 LIGHT UTILITY VEHCLE OPERATIONS DURING URBAN WARRIOR

MDSClass: Unclassified
MDSDTG: 081946Z FEB99
MDSFrom: NAVAIRSYSCOM PMA TWO TWO SIX CHERRY POINT NC//014//
MDSPrec: Routine

ADMINISTRATIVE MESSAGE

ROUTINE

R 081946Z FEB 99 ZYB PSN 071302M13

FM NAVAIRSYSCOM PMA TWO TWO SIX CHERRY POINT NC//014//

TO CG MCWL QUANTICO VA

INFO CG FIRST FSSG//COS/G3/G4//
CG FIRST MARDIV//COS/G3/G4//
CG I MEF//COS/G3/G4//
CG MCCDC QUANTICO VA//COS/G3//
CG MCWL QUANTICO VA//AVN//
CG THIRD MAW//COS/G3/G4/AVN//
COMCABWEST EL TORO CA//COS/GS//
COMMARFORPAC//COS/G3//
COMPHIBGRU THREE//N3/N4/CCO//
COMPHIBRON FIVE//N3/N4//
CSS ENTERPRISE//S3/S4//
FIRSTBN FIFTH MAR//S3/S4//
HMM ONE SIX ONE//S3/S4//
MAG SIXTEEN//S3/S4//
USS BONHOMME RICHARD
USS CORONADO

UNCLAS

MSGID/GENADMIN//

SUBJ/FLYER 21 LIGHT UTILITY VEHCLE OPERATIONS DURING URBAN WARRIOR /ADVANCED WARFIGHTING EXPERIMENT (AWE)//

REF/A/MSG/CG QUANTICO VA/191330ZJAN99//

REF/B/DOC/A1-H46AE-CLG-000/01FEB96//

REF/C/DOC/A1-H46AE-NFM-000/15JUL96//

NARR/REF A IS REQUEST FOR FLIGHT CLEARANCE TO INTERNALLY LOAD THE FLYER 21 V-22 VEHICLE INTO A CH-46E AND CONDUCT FLIGHT OPERATIONS WHILE THE VEHICLE IS EMBARKED. REF B IS H-46 CARGO LOADING MANUAL. REF C IS CH-46E NATOPS MANUAL.//
POC/BRIAN RISO/MAJOR/H46 APMSE/-/TEL:DSN 451-7152
/TEL:COMM (252) 466-7152/TEL:FAX (252) 464-8477//

RMKS/IN RESPONSE TO REF A. THE FLYER 21 V-22 MEETS THE DIMENSIONAL LIMITS, CG LIMIT AND WEIGHT LIMITS SPECIFIED IN REF B. THE RECOMMENDED TIEDOWN CONFIGURATION USING A TOTAL OF FOUR 5000 POUND TIEDOWN DEVICES IN A CROSSING PATTERN FORWARD AND AFT OF THE VEHICLE DOES NOT MEET THE RESTRAINT CRITERIA OF REF B, WP 005, PAGE 15. THE AIRCRAFT TIEDOWN FITTINGS WILL NOT WITHSTAND THE CRASH LOADS OF THE FLYER 21 V-22. AUTHORITY TO TRANSPORT THE FLYER 21 V-22 LOADED INTERNALLY AND SUBJECT TO REF B AND REF C IS AT THE DISCRETION OF THE TYCOM. THE FLYER IS LIGHTER THAN THE M151 TRUCK AS SHOWN IN REF B.

P 005, PAGE 34 WHICH HAS BEEN TRANSPORTED BY THE H-46.//

BT
NNNN

From: MCWL-MDS
Sent: Thursday, February 18, 1999 8:41 PM
To: MCWL All Messages
Subject: FLYER 21 LIGHT UTILITY VEHICLE OPERATIONS DURING URBAN WARRIOR

ADMINISTRATIVE MESSAGE

ROUTINE

R 170916Z FEB 99 ZYB PSN 126332M17

FM COMNAVAIRPAC SAN DIEGO CA//N421C//

TO CG THIRD MAW//ALD//
NAVAIRSYSCOM PMA TWO TWO SIX CHERRY POINT NC//014//

INFO NAVAIRSYSCOM PMA TWO TWO SIX CHERRY POINT NC//3.1.4E//
CG MCWL QUANTICO VA
CG FIRST FSSG//COS/G3/G4//
CG FIRST MARDIV//COS/G3/G4//
CG I MEF//COS/G3/G4//
CG MCCDC QUANTICO VA//COS/G3//
CG MCWL QUANTICO VA//AVN//
COMCABWEST EL TORO CA//COS/GS//
COMMARFORPAC//ALD//
COMPHIBGRU THREE//N3/N4/CO//
COMPHIBRON FIVE//N3/N4//
CSS ENTERPRISE//S3/S4//
FIRSTBN FIFTH MAR//S3/S4//
HMM ONE SIX ONE//S3/S4//
MAG SIXTEEN//S3/S4//
USS BONHOMME RICHARD
USS CORONADO

UNCLAS //N03000//

MSGID/GENADMIN/COMNAVAIRPAC//

SUBJ/FLYER 21 LIGHT UTILITY VEHICLE OPERATIONS DURING URBAN WARRIOR
/ADVANCED WARFIGHTING EXPERIMENT (AWE)//

REF/A/GENADMIN/CG QUANTICO VA/191330ZJAN99/NOTAL//

REF/B/GENADMIN/NASC PMA 226/081946ZFEB99//

REF/C/GENADMIN/CG THIRD MAW/161130ZFEB99//

t

REF/D/GENADMIN/NASC PMA 226/172004ZFEB99//

REF/E/DOC/A1-H46AE-CLG-000/01FEB96//

REF/F/DOC/A1-H46AE-NFM-000/15JUL96//

NARR/REF A IS REQUEST FOR FLIGHT CLEARANCE TO INTERNALLY LOAD THE FLY 21 V-22 VEHICLE INTO A CH-46E AND CONDUCT FLIGHT OPERATIONS. REF B RESPONSE TO REF A, STATES WILL NOT WITHSTAND THE CRASH LOADS OF THE FLYER 21 V-22. REF C RADDR REF B FORAC. REF D REQUEST TYCOM APPROVAL TO OPERATE WITH THE FLYER-21. REF E IS H-46 CARGO LOADING MANUAL. REF F IS CH-46E NATOPS MANUAL.//
POC/C. R. OECHSEL/LCDR/N421C/-/TEL:(619) 545-4954/TEL:DSN 7350-4954//

RMKS/1. IRT REFS C AND D, AUTHORITY TO TRANSPORT INTERNAL CARGO MEETING DIMENSIONAL LIMITS, CG LIMITS, AND WEIGHT LIMITS SPECIFIED IN REFS E AND F IS AN OPERATIONAL ISSUE AND NOT SUBJECT TO TYCOM APPROVAL.//

BT
NNNN

Sparks Mr Grant M

From: Devin Maj Timothy J
Sent: Friday, January 29, 1999 3:10 PM
To: 'Cook, Todd J'
Cc: 'DPender463@aol.com'; Sparks Mr Grant M; Kruger, Martin; Langford, John; Lee, Kristopher; Lumpkin, Gregory; MCMAINS, JAMES; Scheffler, William
Subject: Flyer info

Todd,

Spoke to Flyer, the answers to your questions follow:

1. As for loading, the degree of difficulty associated w/ a front first or rear first loading is roughly the same. The vehicles orientation in the A/C is dictated by the operational mission. Backed in when being delivered to a LZ for quick egress and front loaded when leaving a LZ. We request clearance for both back-in and front-in loading/tiedown/operation

2. CG. The vehicle is 179 inches long. Measured from front to rear the CG is 91 inches from the front. Measured from rear to front the CG is 79 inches from the rear. CG delta = 11 inches.

3. There is a parking brake however, IAW Flyer SOP it is not used while the vehicle is tied down in the helicopter. The only restraint system is that of the cargo strap tiedown arrangement.

4. For the 4 strap tiedown configuration shown on the FAX, frame mounted eyebolts are not used. Instead, the cargo strap is looped around the vehicle frame itself with both ends of the strap connected to the 5,000 # cabin floor tiedown ring. Frame mounted eyebolts are used when the tiedown configuration uses 8 cargo straps as depicted on the elevation view. The additional 4 vehicle mounting points as depicted on the elevation view by triangles are where the eyebolts are located. I will have the strap angle data for these points on Monday.

5. Per the CH-46 CLG, the vehicle is loaded between stations 210 and 350 regardless of orientation. Specific cabin floor tiedowns are shown on the Plan view.

6. Plan view angles: front 56.7 rear 33.3
   Front view angles: 46.5
   Elevation view angles: front 52 rear 18.3

7. Nomenclature. Flyer 21 stands for 21st century and 2 for 1 i.e. you can stack one vehicle on top of another. Flyer V-22 is the narrow version of Flyer 21 (Flyer 21 N) and is CH-46/V-22 compatible. The wide version (Flyer 21) is used w/ CH-53's.

One last question. I haven't had any luck trying to get the same clearance approval for operation in CH-53E's. Do you think we can use any of this data, or do you know anyone who can help me w/ a CH-53E clearance? Perhaps it's you.

I'll be in touch. Thanks. Tim

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Marine Corps Warfighting Lab (MCWL)/Flyer vehicle LOADEX 2-3 Dec 98

Flyer Group, in coordination with the MCWL and 3d Marine Aircraft Wing's HMM-165 (CH-46) and HMH-465 (CH-53) squadrons at MCAS Miramar and VMGR-352 (KC-130) squadron at MCAS El Toro, demonstrated the potential for a major advancement in the deployment of military vehicles in support of Operational Maneuver from the Sea (OMFTS). The demonstration included: (a) loading of a narrow Flyer 4-wheel drive vehicle into a CH-46 helicopter; (b) loading two standard width Flyer vehicles into a CH-53E; and, (c) loading six standard Flyer vehicles into a KC-130. This exercise was in preparation for Flyer Group support of Exercise URBAN WARRIOR.

This LOADEX has demonstrated that:

1. CH-46 can internally carry one Flyer vehicle (3000 lb. curb wt.) without significant reduction in operational radius.
2. CH-53E can carry two Flyer vehicles internally while carrying a stack of two sling loaded externally.
3. KC-130 can carry three Flyer vehicles single file, or six vehicles stacked. (Stacking can occur either outside of the aircraft before loading or inside the aircraft as part of the loading. Stacking is done by driving one vehicle on top of another vehicle.)

At the present time:

1. There are no operational vehicles that can be carried internally by the CH-46, or MV-22. (Based on this LOADEX, and examination of MV-22 cargo bay measurements, Flyer Group believes the MV-22 will be able to internally carry one narrow Flyer vehicle.)
2. No HMMWV can be carried internally in the CH-53E—one is sling loaded externally.
3. Two HMMWV's are the operational load for the KC-130.
4. Movement of vehicles by sea or rail is normally one vehicle per space/footprint.

The stacking design of the Flyer vehicle system will allow strategic and tactical deployment of double the number of vehicles with the same amount of lift, e.g. stacking allows two Flyers to be loaded into a 20 ft ISO shipping container. This is a tremendous logistical advantage for OMFTS operations.

Flyer Light Strike/Light Tactical Vehicle (LS/LTV) systems are non-developmental items (NDI) that have been extensively tested and evaluated, are in production, and in military use in Singapore and Indonesia. In addition to their deployability advantages, Flyer vehicles provide exceptional off-road mobility, carry 3000 lb. payloads (1:1 wt. to payload), and are readily converted in the field to meet Marine Air-Ground Task Force (MAGTF) Command Element, Ground Combat Element, Aviation Combat Element and Combat Service Support Element requirements.

The enclosed photographs and video document December 98 MCWL/3d MAW LOADEX.